CLEAN WATER

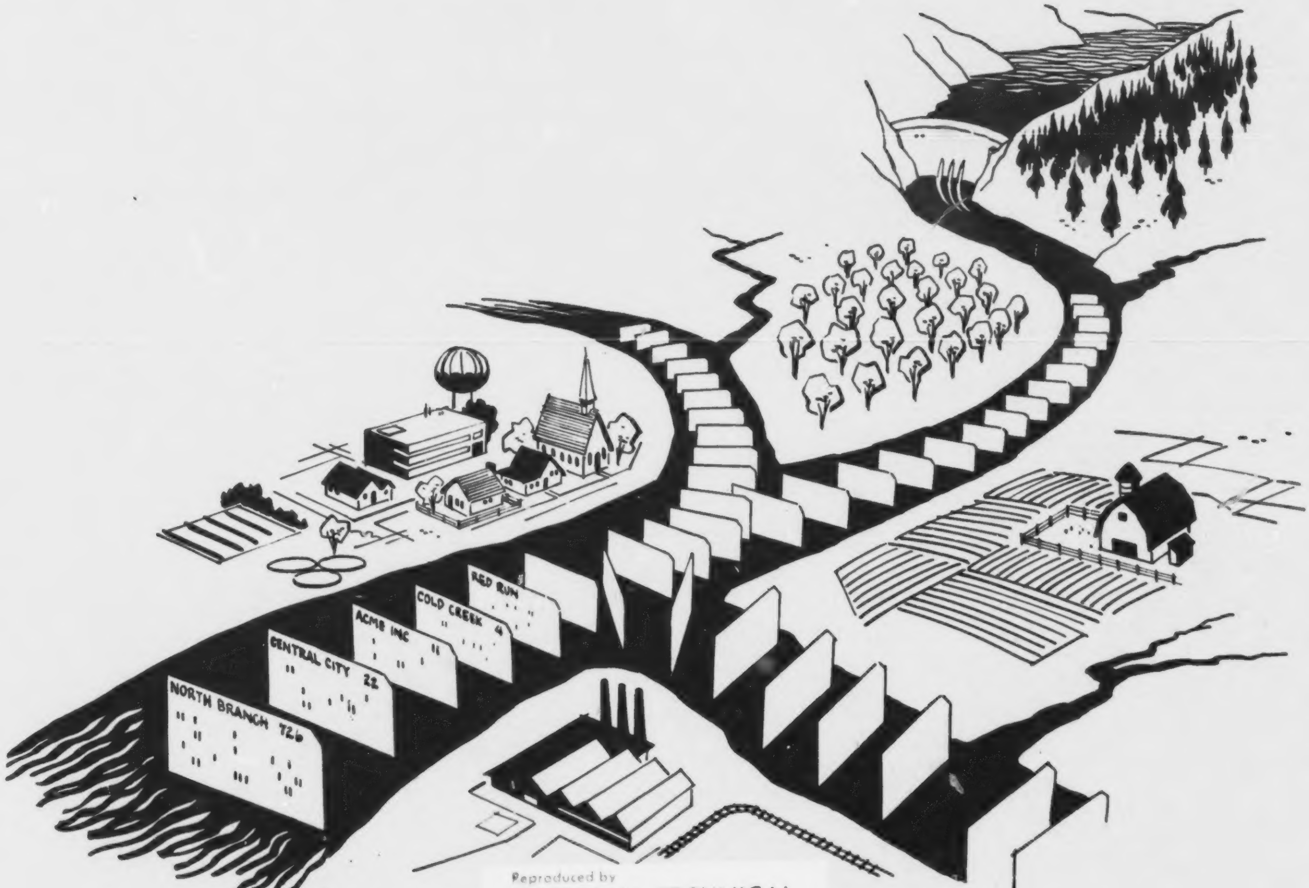
WATER POLLUTION CONTROL RESEARCH SERIES ● 16110 FRU 12/71-1

W 72-10307

PB 210 409

The River Basin Model:

AN OVERVIEW


RED RUN
COLD CREEK 4
ACME INC 11
CENTRAL CITY 22
NORTH BRANCH 726

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U S Department of Commerce
Springfield VA 22151

U.S. ENVIRONMENTAL PROTECTION AGENCY

113

WATER POLLUTION CONTROL RESEARCH SERIES

The Water Pollution Control Research Series describes the results and progress in the control and abatement of pollution in our Nation's waters. They provide a central source of information on the research, development, and demonstration activities in the water research program of the Environmental Protection Agency, through in-house research and grants and contracts with Federal, state, and local agencies, research institutions, and industrial organizations.

Inquiries pertaining to Water Pollution Control Research Reports should be directed to the Chief, Publications Branch (Water), Research Information Division, R&M, Environmental Protection Agency, Washington, D. C. 20460

SELECTED WATER RESOURCES ABSTRACTS

INPUT TRANSACTION FORM

1. Report No.

W 72-10307

5. Report Date

6.

8. Performing Organization Report No.

THE RIVER BASIN MODEL: AN OVERVIEW,

[redacted]

EPA Program

16110 FRJ 12/71-1

Envirometrics, Inc., Washington, D.C.

13. Type of Report and Period Covered

12. Sponsoring Organization (Water Pollution Control Research Series)

~~Prepared for: Office of Research and Monitoring,~~ U.S. Environmental Protection Agency, ~~Project #16110 FRU, Contract # 14-12-959,~~ December, 1971. 109 p, 34 fig, 27 ref, 6 append.

The RIVER BASIN MODEL is a man-machine simulation model, used primarily to replicate the interactions taking place, within a real or hypothetical area, between the local water system and the full range of economic, social, and governmental activities of that area. It is a water resource model representing supply of, demand for, and quality of water, but it is also a labor market model, a land use and assessment model, and several more; it is a model of an entire regional system with water a subsystem realistically interacting with all the other major subsystems; the output from the operating programs of the computer package illustrate the impact that the water system has on such phenomena as housing selection, employment, and government budgetary activity. Model users are given control over all the resources of the local area being represented. Most of the local business and population use municipally supplied water which must be drawn from the local water system and treated if necessary. The model users may make a wide range of private and public policy decisions which affect the simulations for each of the above phenomena, and which impact the environmental quality of the represented area. (Bell-Cornell)

(see W72-10308 thru W72-10314)

17a. Descriptors

*Regional analysis, *Resource allocation, *Decision making, *Simulation analysis, *Computer programs, *Mathematical models, *Land use, *Water users, *Water demand, *Training, *Water pollution, *Effects, *Treatment, *Population, Migration, Water disposal.

17b. Identifiers

*Social dissatisfaction, *Gaming-simulation, Holistic models.

Copy available from GPO Sup Doc
, $1.00 ; microfiche
from NTIS as PB 210 409, $0.95.

06A, 06B, 06D, 05G

	19. Security Class. (Report) 20. Security Class. (Page)	21. No. of Pages 22. Price	**Send To:** WATER RESOURCES SCIENTIFIC INFORMATION CENTER U.S. DEPARTMENT OF THE INTERIOR WASHINGTON, D.C. 20240

Janet Bell	Cornell

The RIVER BASIN MODEL:

An Overview

by

Envirometrics, Inc.
1100 17th Street, N.W.
Washington, D.C. 20036

for the
Office of Research and Monitoring
Environmental Protection Agency

Project #16110 FRU
Contract # 14-12-959

December, 1971

EPA Review Notice

This report has been reviewed by the Environmental Protection Agency and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 - Price $1.00

ABSTRACT

The RIVER BASIN MODEL is a man-machine model that can be use to represent in a suggestive fashion the interactions that take place within a real or hypothetical regional area between the local water system and the economic, social, and governmental sectors of that area. The computer portions of the model are a synthesis of several hundred sub-programs that deal with such regional phenomena as migration, housing selection, water supply, water quality, physical deterioration, employment, transportation, leisure time allocation, public school allocations, shopping patterns, and terminal use.

The human portions of the model allow its users to make decisions that deal with population and economic growth, water pollution abatement, recycling of water, salaries, rents, prices, land transfers, leisure time allocations, voting, boycotts, property assessment, tax rates, budget appropriations, school operation, highway operation, public construction, utility service, municipal service, water service, recreation availability, zoning, and many more. Through the computer and human portions of the model, the holistic workings of a regional river basin area may be represented for purposes of training decision-makers, simulating the aggregate impacts of alternative decisions, and performing research on the regional system itself.

When used in a gaming format, the economic decision-makers represent major corporations that allocate financial resources, operate existing businesses, and exercise the economic power associated with the control of economic assets. Social decision-makers represent population groups in one of three socio-economic classes who reside in different parts of the regional area. Government decision-makers represent local government departments and elected officials who provide either a departmental service or exercise budgetary power.

The RIVER BASIN MODEL in its present form is not usable as a predictive device. Rather, its primary function is to replicate the dynamic and interactive decision-making environment that faces persons from all interest groups who are concerned with doing something about water pollution control and the quality of the regional environment.

CONTENTS

Sections		Page
I	CONCLUSION	1
	Summary	1
	Strengths and Limitations of the River Basin Model	3
II	RECOMMENDATIONS	7
III	INTRODUCTION	9
IV	BRIEF DESCRIPTION OF THE MODEL	11
	Regional Area (The Local System)	13
	Activities	17
	Water Component	21
	The River Basin Model As a Systemic Model	22
V	USES AND USERS OF THE MODEL	25
	Using the Model	28
	Model Features	30
VI	MODEL OUTPUT	33
	Maps	33
	Tabular Computer Output	36
	Indicators	40
	The River Basin Model as a Set of Regional Accounts	40
VII	MODEL INPUTS	45
	Initial Director Inputs	45
	Player Inputs	46
	Periodic Director Inputs	51
	Summary	51
VIII	EXPLANATION OF THE WATER COMPONENT	55
	Water Quality Ratings	55
	Water Use and Sources of Water	55
	Pollutants Generated	62
	Pollution Monitoring	62
	Pollution Treatment	65
	Effects of the Water Quality Index	65
	The Water and Sewer Office	68

Preceding page blank

CONTENTS (Continued)

Sections Page

IX THE INTERACTION OF THE WATER SYSTEM WITH THE REMAINDER OF THE MODEL 69

Operating Programs 74
Interrelated Activities (Subsystems) 79

X APPENDICES 83

FIGURES

Figure		Page
1	Economic Activity Map	14
2	Water Component Map	15
3	Economic Activities in the River Basin Model	18
4	Example of How Population Units Are Affected by the Major Operating Programs of the Model	20
5	Inputs to the River Basin Model	26
6	Economic Status Map	34
7	Map Output	35
8	Tabular Output	37
9	Summary Migration Statistics	39
10	River Quality During Surface Water Process	41
11	Quality of Life Index	42
12	Water Quality Map for TWO CITY	43
13	Available Decisions	47
14	Sample of Inputs and Edits	50
15	Interaction Between the User and the River Basin Model	52
16	Interaction Between the Water Module and Other Parts of the River Basin Model	56
17	Water Quality Ratings and Pollutants	57
18	Definition of the Nine Comprehensive Water Quality Levels	58
19	Water Quality Map	59
20	Water Requirements for Private Economic Activities	60
21	Pollution Generated by Economic Activities	63

FIGURE (Continued)

Figure		Page
22	Examples of the Ambient and Point Source Sampling Stations Reports	64
23	Effectiveness of Treatment Types: Percent of Pollutant Removed	66
24	Components of the Quality of Life Index	67
25	Interaction Between the Water Component and the Three Sectors of the Model	70
26	Interactions of the Water Quality Agency With Parts of the Local System	71
27	Concerns of the Water and Sewer Office	73

SECTION I

CONCLUSIONS

Summary

The water sub-model contains a number of elements desired in a model that is to be used to illustrate the comprehensive decision-making environment within which water resource decisions are made.

First, water is used in varying amounts by all of the different private activities in the model. Some of the industrial activities (surface water users) demand such large quantities of water that they can only be satisfied by drawing water directly from the same parcel of land on which they are located. Agricultural activities use ground water and may pollute nearby water bodies through run off as a function of the farm type and fertilizer used. All other private activities have the potential for creating water pollution through their dumpage into the municipal sewer system.

Second, many of the physical features of water are represented. For example, the percent of the surface of a parcel consumed by water may be dealt with. Water volume, rate of flow, and direction are also shown. Construction costs for roads are increased (representing bridges and/or tunnels) when they cross rivers. Flooding probabilities are represented and damage to activities located in the flood plain are a possibility.

Third, transportation terminals linking the local system to outside markets are able to be located on bodies of water, thereby representing in an approximate way shipping ports.

Fourth, water quantity and quality affect the amount of business generated at major recreation areas (which serve tourists and generate business for local commercial establishments.

Fifth, the pollution generated by industries, businesses, residences, and municipal sources is measured, and the impacts on the rest of the system are represented.

Sixth, the hazards to health (dollar costs and time lost) and to the physical environment (deterioration of buildings) resulting from pollution and flooding are represented.

Seventh, the location of treatment plants (intake and outflow separately) and the level of treatment (chlorination, primary, secondary or tertiary) is represented.

Eighth, the local water quality agency will be able to undertake legal, treatment, and/or public relations approaches to the water quality problems of the local area. Seven types of pollution are represented in the model. These individual pollution types are combined into a single water quality index for ease of understanding on the part of the model users.

Ninth, comprehensive planning and controls may be undertaken by the users of the model. This planning may relate to land use, development zones, utilities, zoning, transportation, and many other government services.

Tenth, a number of other regional level planning activities (such as multi-county cooperation, utility service, water supply, transportation, economic growth, and areawide pollution control) may be dealt with by the users of the model.

In sum, the River Basin Model is a general man-machine simulation of a regional environment. The model interrelates and calculates the effects of decisions made for the regional area represented by the model on a year to year basis.

The model is not designed to show its users what ought to be or to indicate what policies should be made. Rather, the model generates information on and indicators of many types of economic, governmental, social, and physical phenomenon for the represented area. It is up to the users of the model to decide which of the indices and measures are important to them. Therefore, even though the model does not set a standard for "good performance" or "success", it does contain many measures and indices necessary to evaluate "good performance" and/or "success" once the users have defined what these normative terms mean. Thus, the users provide the real normative input into the model through their interpretation and evaluation of the status of the area and its water subsystem at various points in time.

Comprehensive regional systems modeling is still in its infancy. The River Basin Model represents an early point along what will probably be a continuum of evolutionary comprehensive models that deal with the regional environment (in a broad sense of the term) and with water resources as a subsystem within this larger system.

Two forms of evolution can be made in the River Basin Model. The first is evolving good model accounts, parameters and coefficients. This will involve empirical research. Unlike most modeling efforts, the River Basin Model is a model that has been completed without any original data collection and with very little equation fitting. With a comprehensive and holistic model it is preferable to have a complete and operable model before large sums of money are spent on data collection. This does not mean that the model was completed without reference to the past empirical research performed by others. Quite to the contrary, the River Basin Model incorporates the findings of others in many parts of the model. However, it must be realized that the model deals with many relationships that have not yet been researched at all. For instance, studies do not exist that deal with employment selection on a micro level. On the other hand, some previous work has been done on such things as industrial land consumption by industry type and employment needs by business type. The results from these studies have been incorporated into the design of the River Basin Model.

A second type of evolution is to modify and add to the basic relationships represented in the River Basin Model. It is not claimed that the model contains every factor that a regional decision-maker or water resource planner wants to consider when making a decision. It does, however, contain many factors -- more than most previous models. Because of the modular design of the model it may be modified and additions to it may be made with a minimum of difficulty. An advantage of the River Basin Model is that new modules are made a part of an operable holistic model and the phenomena represented are not treated in an isolated fashion.

Strengths and Limitations of the RIVER BASIN MODEL

Two of the strengths of the River Basin Model are that it is a very general model and a very flexible model. It is general in that it can be used to represent innumerable different starting positions. It is flexible in that is may be used by its director and players for a large number of purposes.

The limitations of the model are that the representations of actual areas and specific problems are yet to be researched and use of the present model with the hypothetical data base cannot be used for forecast or prediction purposes. This certainly does not mean that the basic model form of the River Basin Model could not be used to represent given areas.

But the present data base of the model contains too much aggregation and untested parameter values to realistically be employed as a simulation of a particular area (as this term in normally used) or to gain reliable estimates of future impacts from present decisions. At best, the present configuration can be said to yield results which tend to be in the right direction and of the correct magnitude.

The model can, however, be used to represent at various levels of sophistication the census year status of American regions and urban areas. One of the two sample starting positions for the River Basin Model is an area called RAYWID CITY. The data for this regional area was derived from 1960 census data and other sources for the Cleveland-Akron metropolitan areas in Ohio. The following table indicates a few of the similarities and differences between the local system represented by the River Basin Model in the form of RAYWID CITY and the actual Cleveland-Akron Region (originally chosen because the Cuyahoga River Basin lies within its six-county boundaries).

Characteristic	Cleveland-Akron SMSA (Actual 1960 Data)	RAYWID CITY (the Cleveland-Akron area as represented by the model)
Population	2,515,000	2,508,000
Counties	6	3 aggregated jurisdictions
Land Area (square miles)	2,424	2,519
Total Personal Income Earned (millions)	5,658	5,600

A moderate amount of time (about six man-months) was spent collecting and loading actual data to get a starting position that represented the Cuyahoga River Basin to the extent that RAYWID CITY does. More time could have been spent and a slightly more accurate starting position could have been achieved. The important point, however, is that no matter how much time was spent on the data collection and fitting, the River Basin Model with its present aggregation assumptions is not able to represent the Cuyahoga River Basin as closely as all might like, and certainly not closely enough to deal with all of the very detailed regional problems and their solutions.

For example, the smallest increment of industrial employment is 10,000 workers. The smallest increment of land (when the land from all six counties is included) is 40 acres. The smallest school facility is for 20,000 children from all age levels. Total water pollution is represented by seven pollutant types and a single pollution index is assumed to have some value as an indicator of water quality. For a good many purposes, these assumptions are too heroic. On the other hand, for a number of other purposes, these assumptions allow the model to collapse time and complexity so that the users of the model (be they professionals, laymen, or students) are able to grasp the interrelatedness of decisions in the economic, social, and government spheres of a regional area.

In the Cuyahoga area, for example, the model could be used to bring decision-makers together to look at and try to solve the problems of a river basin that very much looks like their own. They see and take part in the financial concern for jobs, the interaction among separate political jurisdictions, the legal problems of enforcement, and the multiple alternatives to water quality control.

The first benefit of the model in this case is the participation in a simulation of a local system over a number of years in which they collectively have the opportunity to define problems, develop strategies, implement plans, act upon feedback, and evaluate the changing status of the local system and all in a laboratory environment.

As a laboratory, the model provides an opportunity for its users to practice making decisions for a simulated area before they are forced to do so in real life. This can be a service to water resource planners who may need to be aware of the broad impacts of their water resource decisions. This can be useful to local professionals who seldom look at their impacts on the total system. It is useful to citizens who need to see the complexity of decision-making. It is useful to students, who seldom get the chance to make policy decisions during their academic careers.

The use of real data may assist some of the above types of users to benefit from the model but even the use of a hypothetical starting configuration (such as for the TWO CITY starting position) can provide many insights into the complexities of and interrelatedness among regional decisions. Ultimately, the strength of the River Basin Model is that it places water management decision-making into a realistic decision-making environment in which the same conflicts that emerge in real life are likely to emerge and the same types of solutions may be developed and implemented.

SECTION II

RECOMMENDATIONS

This final report and the RIVER BASIN MODEL manuals (those for the player, director, and computer operator) should be duplicated in large quantities and be distributed to the following types of recipients:

1. EPA Training Officials
2. EPA personnel who deal with citizen action groups
3. Higher level schools that have environmental studies programs and water resource programs
4. Multi-County Planning Agencies

Critical evaluations and suggested changes should be encouraged from all recipients of these materials.

Several demonstration runs of the model should be undertaken on differnet user groups:

1. Researchers - to determine if this holistic modeling technique has any immediate usefulness in developing a more comprehensive approach to water quantity and quality issues.

2. Educators (EPA and universities) - to compare the use of the RIVER BASIN MODEL with alternative educational techniques in 1) getting students to see the complexities of water management decision-making in a regional context, 2) stimulating students in their outside readings, 3) developing a systematic approach to community-wide goal setting and evaluation, and 4) generating an interest in delving deepter into the study of water quality indexes, environmental indexes, social dissatisfaction, costs associated with treatment, and regulatory alternatives to control water quality.

3. Multi-county Planning Agencies - to test the model as a device for bringing persons from adjacent jurisdictions together to look at problems in a simulated environment that are similar to the ones they face in their own area. Also to test the model's ability to help people of diverse backgrounds to communicate to one another using the common language contained in the model.

It is also recommended that if the preliminary response to the model is favorable, EPA consider going ahead with the further evolution of the model by fine-tuning many of its parameters using a ten year test with actual 1960 to 1970 data. This would bring the model to the point where it would be dealing with parameters based upon the most recent data possible, rather than on 1960 data.

Preceding page blank

SECTION III

INTRODUCTION

Water resource planners have been accustomed to developing and using computer models that focus to a large extent on the water subsystem of the entire river basin or regional system. This focus has been so strong that the models have not been able to deal simultaneously with a wide number of concerns that are directly or indirectly related to water resource planning, such as the effect of pollution regulations on employment of different segments of the labor force, employment by different segments of the business and government community, percent of incomes spent for various types of water uses, externalities (market values of homes, land use activity, assessed value of land, etc.) associated with water quality and use, and the financing of alternative water resource plans. In short, previous water models have not been models of an entire regional system with the water subsystem realistically interacting with all the other major subsystems.

The River Basin Model is a water resource model, but it is also a labor market model, a commercial allocation model, a migration-housing model, a land use and assessment model, a government operations model, and several more. It is a regional systems model. It deals with a full range of factors that impact on the water subsystem and a wide range of factors that are in turn affected by water resource planning decisions.

The River Basin Model deals with groups of people, corporations, and government departments as they interact with one another within a spatially constrained environment. It differs from other water models in that it generates much of the data used as inputs to water models as a result of complementary processes that are a part of the regional system. For example, a typical water model might need inputs as to where industries are located, how much they earn, what their tax payments are, and how many people they employ. In other words these are normally exogenous inputs to the model. The RIVER BASIN MODEL makes these and other factors that relate to the local water subsystem endogenously determined factors that are either human inputs or generated by computer simulations.

The River Basin Model recognizes that many concerns of the water resource planner may be handled only within the confines of a holistic model of the regional system. To deal with the economic, social, and governmental impacts of water resource planning calls for a model that incorporates

Preceding page blank

and simulates the interaction of many subsystems other than that for water. Some of these subsystems are directly related to the water subsystem while others are related in only an indirect way. The River Basin Model is an attempt to represent in an operational model all of these major subsystems, and thereby place water resource planning within its realistic perspective.

The River Basin Model, given its present data base, does not, however, represent the workings of an actual regional system with enough accuracy to be used as a predictive device. It has been built using aggregated representations of people, businesses, and government activities. Its primary purpose is to give a holistic view of the workings of a hypothetical regional system and its water subsystem and to allow its users to interact in a dynamic decision-making environment.

SECTION IV

BRIEF DESCRIPTION OF THE MODEL

In a sense, the River Basin Model is a misnomer, because if one places an emphasis on River" it leads one to believe that the model is primarily concerned with water management. The emphasis should be placed on "River Basin", and that term should be interpreted in its broadest context as meaning a geographical area of land. Through its two major components -- human interaction and computer simulation -- the model represents the economic, social, and governmental activity that takes place within the geographical boundaries defined by the river basin or more simply by a group of contiguous counties.

The model is unlike most other simulation or human interaction models. It was not designed to accomplish any one specific purpose. Rather it was designed to let its users represent the major economic social, and government interests that cause a regional system to function and change. As part of the functioning of this regional system, water is demanded by industries and municipal water suppliers and pollution is generated by manufacturing and commercial activities, by people, and by farm activities.

The model is a computer-assisted decision-making tool, in which a number of computer programs simulate major processes that take place in the local system such as migration, housing selection, employment, transportation, shopping patterns, the actual allocation of leisure time, and water quality determination. Users of the model provide inputs to these programs on behalf of business activities in the economic sector, and government departments in the government sector.

Normally, the users of the model are assigned decision-making responsibility for businesses, population units, and departments in a gaming format. This means that users become members of teams that are assigned control of:

1. Economic Assets: cash, land, manufacturing plants, commercial activities, and/or residences.

2. Social Assets: population units that are designated as high income, middle income, and/or low income.

3. Government Assets: power of the budget, taxing and assessing authority, service responsibility, and planning power.

The computer print-outs in time period T provide a detailed description of the regional area represented by the model, and the users of the model evaluate this status as individuals, as team members, and collectively to define problems, establish objectives, develop strategies, implement plans, and react to feedback from the new computer printout for time period T+1.

Regional Area (The Local System)

Since the River Basin Model is a holistic decision-making model for a geographical area that has been pre-loaded into the computer, the choice of the initial regional configuration to be represented is very important.

The model deals with any geographical area and many of its associated economic, social, governmental, and water resource characteristics. Many of these characteristics are represented on a grid map that measures 25 square parcels of land on a side. All of the 625 possible land parcels are of equal size, so the length of a parcel side determines what overall geographical size area may be represented. Or conversely, once the total area to be represented is known, the length of a parcel side may be determined.

The latter approach was used to set the initial parcel side lengths for the model. It was decided early in the project to represent the Cuyahoga River Basin area as one of the two initial starting configurations turned over to EPA.

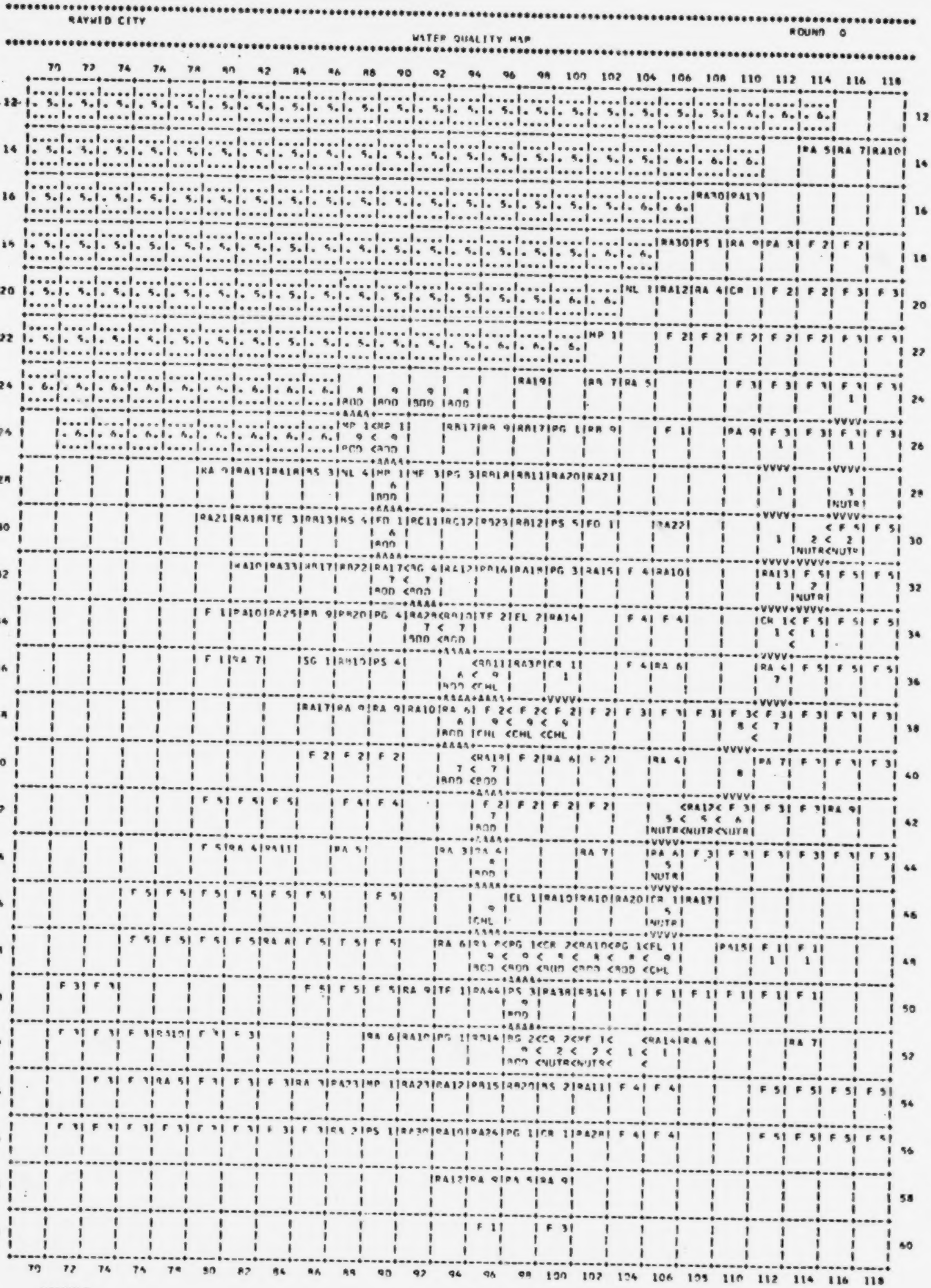
The Cuyahoga River Basin is located within a six county area that also happens to be contiguous with the Cleveland and Akron Standard Metropolitan Statistical Areas. To fit that six county area on the 25 by 25 grid resulted in a choice of 2 1/2 miles for the length of a parcel side for that particular load configuration. Thus each square was equated to 6.25 square miles in area.

The length of a parcel side may be changed rather easily when the model is loaded, but a realistic range of lengths would be from about .1 to 4 miles and a number of other model parameters should be simultaneously altered to correspond with the areal scale change.

Figure 1 shows a map of the economic activity represented by the model for the Cleveland-Akron area. The area is actually called Raywid City in order not to mislead users of the model that a full-fledged attempt had been made to represent that actual area. A research plan has been devised, however, that would fine-tune the model to represent an actual river basin area using 1970 census data. The scope of this project would be about four man-years and a moderate amount of computer time.

Figure 2 shows the representation of the water component within the Raywid City area. Note the map shows that rivers flow through the centers of parcels of land, each parcel length of

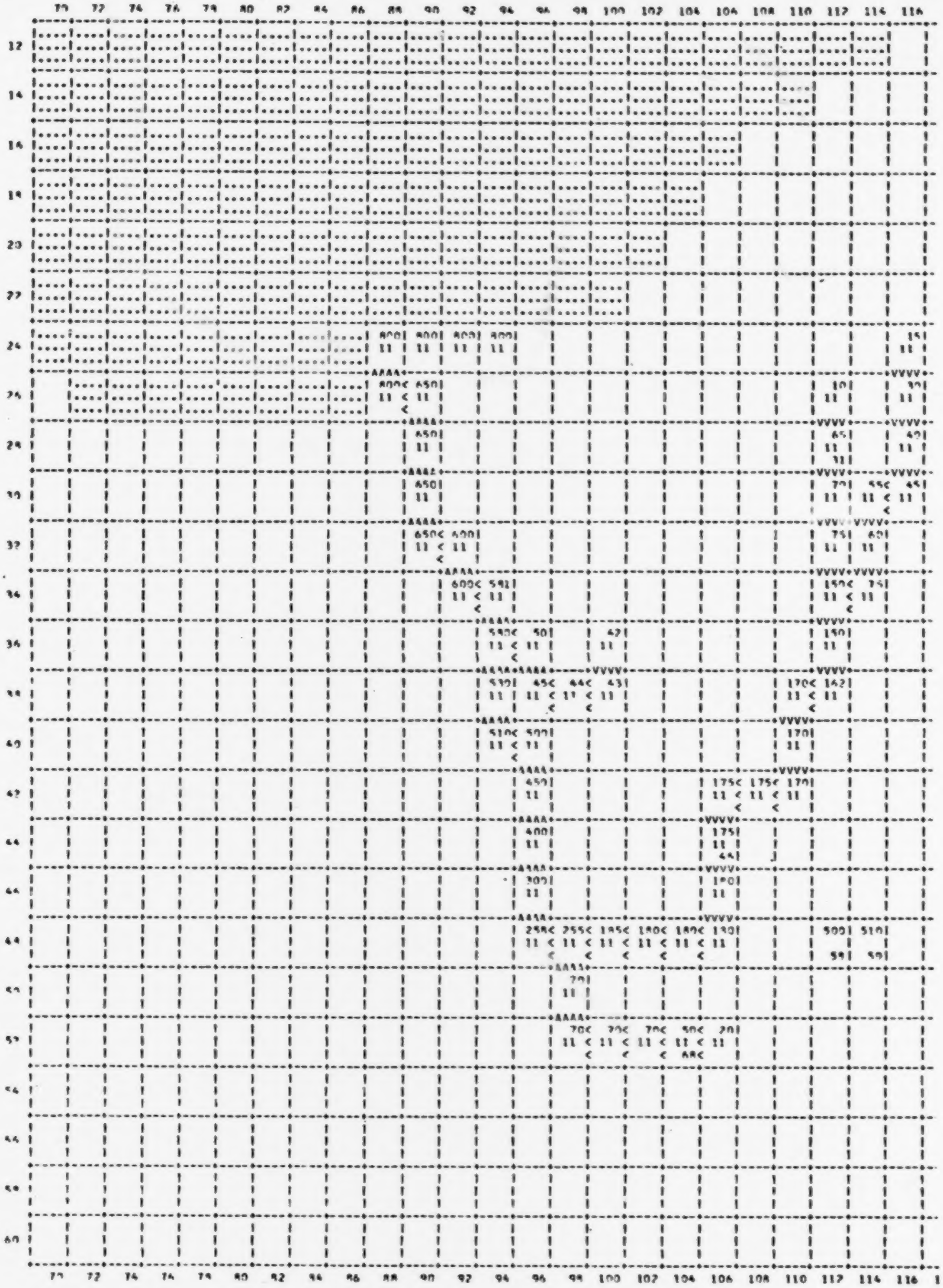
Figure 1


RAYHID CITY
WATER QUALITY MAP
ROUND 0
70 72 74 76 78 80 82 84 86 88 90 92 94 96 98 100 102 104 106 108 110 112 114 116 118
12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60

```
PARCELS                                            PARCEL EDGES
-------                                            ------------
TOP ROW:    ECONOMIC ACTIVITY TYPE                 >AV<  DIRECTION OF FLOW
            AND OPERATING LEVEL
               FARM TYPE IF FARM ON PARCEL         ----  NO WATER FLOWING
MIDDLE ROW: SURFACE WATER QUALITY RATING                 BETWEEN PARCELS
BOTTOM ROW: WORST POLLUTANT
....
....  LAKE PARCELS
....
```

PAYAID CITY ROUND 0

SURFACE WATER MAP


70 72 74 76 78 80 82 84 86 88 90 92 94 96 98 100 102 104 106 108 110 112 114 116
12
14
16
18
20
22
24 800 800 800 800 15
26 800< 650 10 30
28 650 65 31 40
30 650 70 55< 45
32 650< 600 75 60
34 600< 591 150< 75
36 590< 50 42 150
38 539 45< 44< 43 170< 162
40 510< 500 170
42 650 175< 175< 170
44 400 175 45
46 300 190
48 258< 255< 195< 180< 180< 130 500 510 59 59
50 20
52 70< 70< 70< 50< 20 68<
54
56
58
60
11
AAAA
VVVV

PARCELS

TOP ROW: AMOUNT OF SURFACE WATER
ON PARCEL (MGD)
MIDDLE ROW: RATE OF FLOW
BOTTOM ROW: PERCENT OF SURFACE AREA
OF PARCEL IN WATER

....
.... LAKE PARCELS
....

PARCEL EDGES

>AV< DIRECTION OF FLOW
---- NO WATER FLOWING
BETWEEN PARCELS

the river has a water quality rating (a high number is less desirable than a low number on this water quality scale), and which of the seven major pollutants is most responsible for the poor water quality rating. More about this will be said later.

The users of the River Basin Model are assigned responsibility for allocating all of the major economic, social, governmental, and water resources for the local system (the area and its activities represented on the grid map) on a year to year basis. The director of the model (the person conducting the run of the model) makes a number of decisions for the major decision-makers that are outside the local system. A number of computer programs are also available to simulate part of the actions between this local system and the rest of the world.

The initial starting position will show a particular set of allocations of the local system's resources and their effects on the status of the local area. The users of the model evaluate their own particular status within the local system as well as the status of the area as a whole. They then interact with one another in a dynamic decision-making environment in which they collectively have control over the local water quality decisions that will be made, implemented, and reacted to. Some of the model players may have apparently only marginal interest in the local water quality issues because they are pre-occupied with running schools, building roads, earning incomes, producing manufactured goods, building housing, and supplying local goods and services. Others will have maybe more interest as they attempt to be elected into public office, run the planning department, collect taxes, recreate, and develop a generally pleasant environment for their new residential subdivisions. Still others might have a direct and pressing interest in the local water quantity and quality as they attempt to set and enforce water quality standards, supply municipal water, use surface water in their production process, and benefit from major water-based recreation areas.

In short, the entire local system (at a certain level of detail) is represented by the model and its users, and water decisions are placed within their realistic context of having different importance to different individuals as a function of their occupation, location, resources, and personal inclinations.

Activities

The major activities represented in the model may be divided into three major sectors (economic, social, and governmental) and one major subsector (the water component). Each of these sectors has a number of activities that interact with the activities of the other sectors.

The major economic activity is the business operation. Four broad types of businesses are represented in the model: basic industry (manufacturing mostly) that produces goods for export to national markets, service industries that supply goods and services to local system buyers, residential developers and operators who make housing available to the local population, and farming activity which consumes the majority of the land in the region.

Figure 3 shows the detailed economic activities that fall under each of these four broad headings. The economic assets of the local system are divided up among economic teams for their management. In addition to businesses, vacant land, cash, and stock ownership may be given to teams for their use as they see fit. Teams may be set up in such a way that they are specialized (have only heavy industry, only residences, only land, etc.) or diversified (a mixture of several types of assets).

The Social Sector has one basic resource and that is people. The local system's population is divided into clusters of 500 people (or some other size if a program change is made) that are called population units (Pl's). These Pl's are further characterized by an income class (high, middle, or low), average educational level, average savings, number of registered voters, etc. Associated with income class are a number of specific characteristics such as number of workers, number of students, and many preference functions.

Social Teams are created by giving a team decision control for all the Pl's of a given class on specified parcels. A good number of the actions taken by Pl's during the course of a year in the local system are determined by computer allocation models, but the social teams may affect these by making time allocation, boycott, cash transfer, and vote decisions for the Pl's under their control.

A significant part of the River Basin Model centers around how Pl's function within the local system during the course

Figure 3

Economic Activities in the RIVER BASIN MODEL

Basic Industry (sells output at markets outside the local system)

Manufacturing (roughly equivalent to the 2-digit SIC code industries)

FL - Furniture and Lumber
SG - Stone, Clay, and Glass
MP - Primary Metals
MF - Fabricated Metals
NL - Nonelectrical Machinery
EL - Electrical Machinery
TE - Transportation Equipment
FO - Food
TA - Textiles, Apparel, and Leather
PA - Paper
CR - Chemical, Plastics and Rubber

Non-Manufacturing

NS - National Services (such as insurance, research, etc.)

Local Commercial (sells output competitively to local system demanders)

BG - Business Goods
BS - Business Services
PG - Personal Goods
PS - Personal Services

Residential (provide housing space)

RA - Single Family
RB - Garden Apartments (6 times the housing space as RA housing)
RC - High-rise Apartments (25 times the housing space as RA)

Agricultural (consume land and use varying amounts of fertilizer)

F1 - Fruit & Nut
F2 - Vegetable
F3 - Other Field Crops
F4 - Cash Grain
F5 - Tobacco
F6 - Cotton
F7 - Poultry
F8 - Dairy
F9 - Livestock
F10 - Ranchers
F11 - General

of each round of play which represents one year of time in the local area. Figure 4 shows the actions of Pl's as they are affected by the major operating programs.

The Government Sector is comprised of decision-makers who are responsible for a wide vareity of public activities: budget making (appropriations and revenues), land and building assessment, education, municipal services, transportation, planning and zoning, and utilities. The latter activity contains within it the water office that is responsible for the supply of public water. The Water Quality Office may be a part of this department of a separate agency.

Figure 4

Example of How Population Units Are Affected by the Major Operating Programs of the Model

Major Operating Programs	Effect on Population Unit
Migration	Pl's move to the local system, find and change housing within the local system, leave the local system
Water System	Poor water quality incareses dissatisfaction and high coliform count increases health costs and time lost due to illness.
Depreciation	Housing that depreciates becomes less attractive in the migration process.
Employment	Pl's are assigned to full and part time jobs that maximize net income (salary minus transportation costs), employers search for best educated workers.
Transportation	Pl's travel to work by the mode and route that minimizes total costs (dollar plus time), Pl's travel to shopping along the minimum cost routes.
School Allocation	Students of Pl's are assigned to public or private schools based upon the quality of public schools.
Park Allocation	Pl's are assigned to parks within a specified distance of where they live.
Time Allocation	Involuntary expenditures of leisure time are calculated as a function of the success of getting part time jobs, public adult education and the time spent on transportation.
Commercial Allocation	Pl's are assigned to stores at which the total costs are minimized (price plus transportation to the store).

Water Component

The water component is a subsector that, in a sense, cuts across the other three sectors or is a part of each. For example, some of the industrial activities in the economic sector use surface water in their production process and all other economic businesses have some need for municipally supplied water. Population units in the social sector use water as a function of their income class and the type of housing they inhabit. In the government sector, the Utility Department is responsible for supplying the municipal water needs of the residents of its jurisdiction.

Each of the surface water users requires a specified quality of water and must either treat the water they intake or purchase water from a source outside of the local system. Every water user adds some pollutants to the water it returns to the water system. If left untreated, these water discharges may lower the quality of water of the body of water into which they are dumped. Since water users and polluters are located in a geographical space, activities upstream and downstream are affected differently by the dynamically created water quality conditions.

The River Basin Model As A Systemic Model

The River Basin Model may be characterized as a systemic model. That is, it is a model of the interactive workings of the system it represents. The River Basin Model is not a predictive, projective, or normative model. It does not predict a future state of the area represented, although it does show the immediate status of the urban area given all the resources of the system and the policies attached to the use of those resources. Therefore, it is an impact model (one year at a time) rather than any kind of predictive model.

The River Basin Model is not a projection model because it does not extrapolate present circumstances and relationships into the future. In other words, the user of the model does not "turn it on" and generate a set of future states for the area represented. The model cycles in one year increments, and in a sense, it could be used for projection if the user made the year to year decisions for the urban area for a twenty or thirty year time period. But because of the broad scope of the model and the wide range of decisions that are based upon the results of previous decisions in the economic, social, and government sectors, this particular use of the model should not be looked on as a simple task.

Furthermore, the River Basin Model is not a normative or optimizing model. It will not itself generate optimal policy decisions. The model produces a thorough set of indicators and measures of the regional status at discrete points in time (the end of each year) and it is up to the user of the model to apply his own set of objective and subjective criteria to evaluate the absolute or relative quality of the environment. For example, the model will generate measures of water quality along stretches of the river, pollution dumped by various activities, local water deficiencies, poor schools, economic rates of return, housing quality, municipal services quality, social dissatisfaction, etc. and the user of the model must determine the values to be placed on these measures as policy decisions regarding the use of the regional resources are made for future years.

A systemic urban model such as the River Basin Model endeavors to represent the workings of a regional system and its major subsystems. This is done by selecting the major activities that comprise the urban system (people in households, businesses, and government agencies) and representing the actions that they pursue on a year to year basis. Population groups reside in housing, earn incomes, purchase goods and services, take part in leisure activities, utilize government and institutional services, transport themselves as they interact with activities that are spatially separated from their places of residence, and use water. Businesses purchase goods and services, hire labor, require utilities, produce output, sell output, pay taxes, invest earnings, use the transportation subsystem, use water, and generate pollutants that may be treated. Government agencies receive funds, purchase necessary goods and service, hire labor, provide service, and set policy. Most of the departments compete with the water quality office for a slice of the local budget.

SECTION V

USES AND USERS OF THE MODEL

Broadly speaking, there are two types of users of the model when it is employed using a gaming format: the director and the players.

In each use of the model the director sets the major purpose for which the model will be employed. Usually the specific group of players he has in mind will determine his choice of the executive options, such as the starting regional configuration and any round 0 inputs to modify this basic configuration.

As shown in Figure 5, the director may affect the simulated region before play begins by selecting the basic configuration and making changes in it. He may also affect the year to year outside influences on the local system by, among other things, acting as the Federal and State governments with regard to granting aid and imposing regulations. For example, the director could act as an outside government that imposes rigid water quality standards. He could also act as a higher-level government that grants financial aid for the construction of waste treatment facilities, for comprehensive water resource planning, for enforcement and monitoring, etc. The following list is a sample of the executive options available to a director.

1. Choice of Initial Configuration: TWO CITY or RAYWID CITY

2. Round 0 Decisions:

    a. Change Economic Team Holdings - many possibilities.
    b. Change Social Team Holdings - many possibilities.
    c. Change Government Service Levels - give schools and/or municipal services higher or lower use indexes.
    d. Change Local Tax Structures - many possibilities.
    e. Change Salaries, Prices and/or Rents.
    f. Change Maintenance Levels.

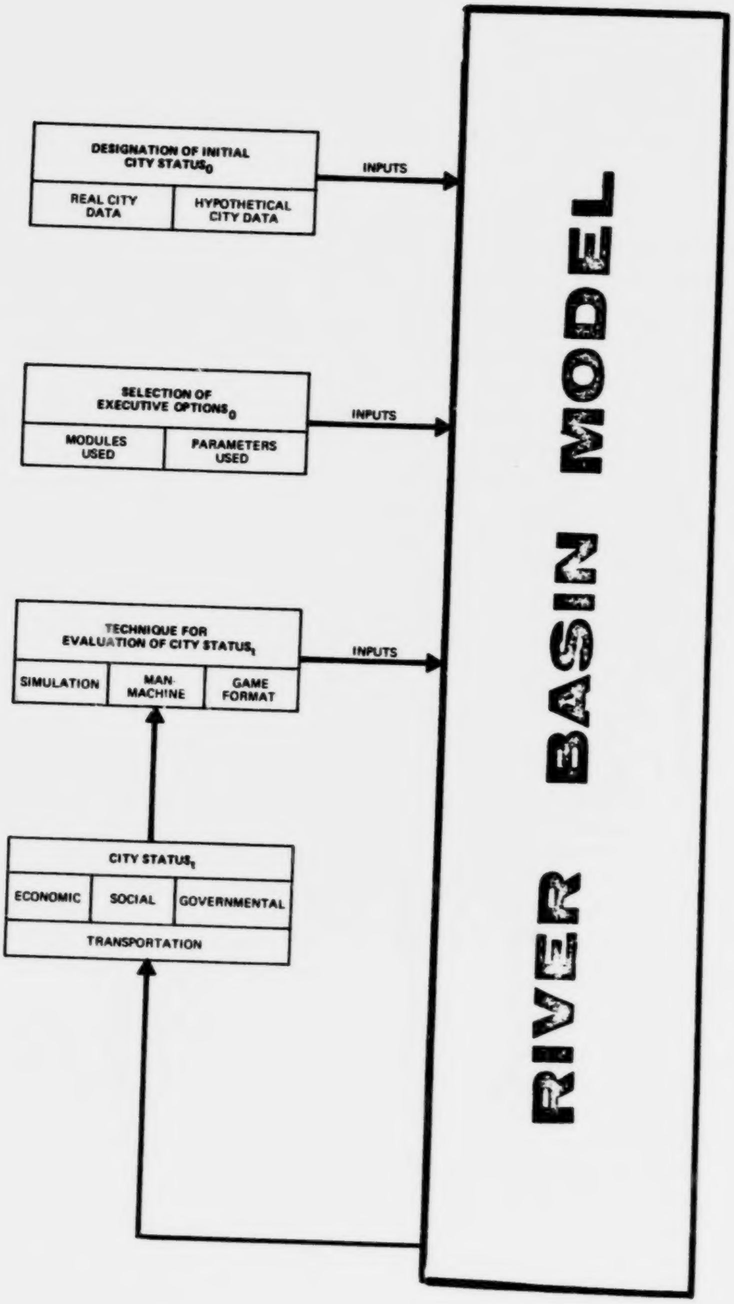
    To achieve:

    a. more or less team specialization or more or less equitable starting positions among teams.
    b. create more or less neighborhood and/or single-class control.
    c. make neighborhood attractiveness vary by altering the quality of public services.

Preceding page blank

Figure 5

INPUTS TO THE RIVER BASIN MODEL


DESIGNATION OF INITIAL CITY STATUS$_0$
REAL CITY DATA
HYPOTHETICAL CITY DATA
INPUTS
SELECTION OF EXECUTIVE OPTIONS$_0$
MODULES USED
PARAMETERS USED
INPUTS
TECHNIQUE FOR EVALUATION OF CITY STATUS$_1$
SIMULATION
MAN-MACHINE
GAME FORMAT
INPUTS
CITY STATUS$_1$
ECONOMIC
SOCIAL
GOVERNMENTAL
TRANSPORTATION
RIVER BASIN MODEL

d. shift to or away from dependence upon property, sales, and/or income taxes.
e. alter rates of return to economic sector or savings for social sector.
f. make area as a whole or parts of it more or less deteriorated.

Using the Model

The River Basin Model is a tool that has utility which is dependent upon the quantity and quality of data loaded into its files, the executive options employed by the director, and the technique used to evaluate the city status and generate inputs to the model. These three types of inputs to the model are illustrated in Figure 5.

Users will use the tool in a way that they find best suits their purposes. It is a flexible model that will take on different forms in the hands of different users. The River Basin Model provides a framework that is common for all regional planners (much as a chemistry lab and the associated chemistry theory provide users of the lab with equal access to the facilities and accumulated knowledge). It allows the planner to use this framework and the computer programs associated with it to achieve a wide range of objectives (much as the chemist may use the lab for instructional, research or production purposes).

Although the River Basin Model as presently developed will not satisfy every need of the planner, it does allow him the opportunity to deal with a large number of regional phenomena which up to now he has not been able to deal with in a simulated and collapsed-time environment.

Users of the model are given control over all the resources of the local area being represented. Some of the local activities use the water subsystem while others do not. As a result of this, the water quantity and quality is of varying importance to the various activities represented by the model.

The River Basin Model is oriented toward user requirements such as generality of representation, flexibility of change, ease of inputs, and readability of output. The model provides, among other things, detail on the repercussions of various water quantity and quality levels and on the effects of water resource decisions on people and business activities. It also illustrates the impact of other decisions on the water subsystem itself.

A wide range of decisions and their consequences may be illustrated by the model. For example, in the economic sector the impacts of pollution regulation decisions may be shown. In the social sector, the effect on housing selection, employment, shopping, and leisure activities are influenced by water resource policies. The impacts of many government decisions may be shown: comprehensive planning programs, quality of life improvements, and many more.

The users of the model may make a wide range of private and public policy decisions which affect the water subsystem and others. The detailed and summary computer output reveals the interactions of these decisions and the collective impact they have on the environmental quality of the represented area. Since each cycle of the model represents the passage of a year of time in the area being represented, the model may be run for as many cycles as the users find desirable.

Model Features

User interaction in the River Basin Model

- requires fewer model assumptions on the part of the designer than most previous models because the users provide much of the nonquantifiable relationships and inputs to represented system
- allows realistic human interaction and reaction
- allows political repercussions associated with water resource decisions, reversal of policy, etc.
- allows human involvement in the decision process

The River Basin Model deals with:

- External Inputs - area characteristics, including the present water subsystem and quality levels
- Internal Inputs - wide range of water resource, economic, social, and government decisions
- Internal Outputs - changes in the resources of the individual decision-makers
- External Outputs - changes in the area characteristics, allocations, assignments, matching of supply and demand, insufficiency of government services, and complete status of the water subsystem.

The River Basin Model is useful to citizens as well as planners because the model output is designed in such a way that it is comprehensive, easy to understand, and quick to retrieve. Thus, regardless of the sophistication of the user, the model will provide the necessary level of information upon which evaluations can be made and decisions can be generated.

The cycles of the model (each set of computer output) represent one year in the life of the area represented by the model. Users provide the evaluation of the current status of the area (in its economic, social, governmental, spatial, and water quantity and quality dimensions). Through a wide range of decision alternatives, they are able to devise strategies and implement policies in an attempt to achieve any set of goals or objectives they devise, as individuals or collectively.

These decision inputs may be generated in a simulation environment (in which a single user or group of users such as water resource planners are given control over all the resources of the local system) or in a game environment (in which individual users such as local officials, students and/or citizens are given control over various resources in the local system).

The River Basin Model has been designed in a modular fashion, so that new modules may be added or existing ones replaced or modified at minimal expense. This modularity means that it is relatively easy to:

- redefine the model (change parameters and coefficients)
- load various regions

This modular feature of the River Basin Model allows it to be truly evolutionary, thus making it a framework that can continually be improved and modified for specific uses.

SECTION VI

MODEL OUTPUT

The model describes and interrelates many of the actual economic, social, and governmental activities that comprise regional areas. The metropolitan area represented by the model is described by three types of computer output: maps, tabular statistics, and indicators.

Maps

The maps show the spatial characteristics of the represented area. The tabular output shows general information of interest to the users of the model as well as specific data concerning businesses in the economic sector, groups of people in the social sector, and government departments in the government sector. The indicators are measures such as the economic rate of return, the social dissatisfaction level, the quality of local government services, and water quality indicators.

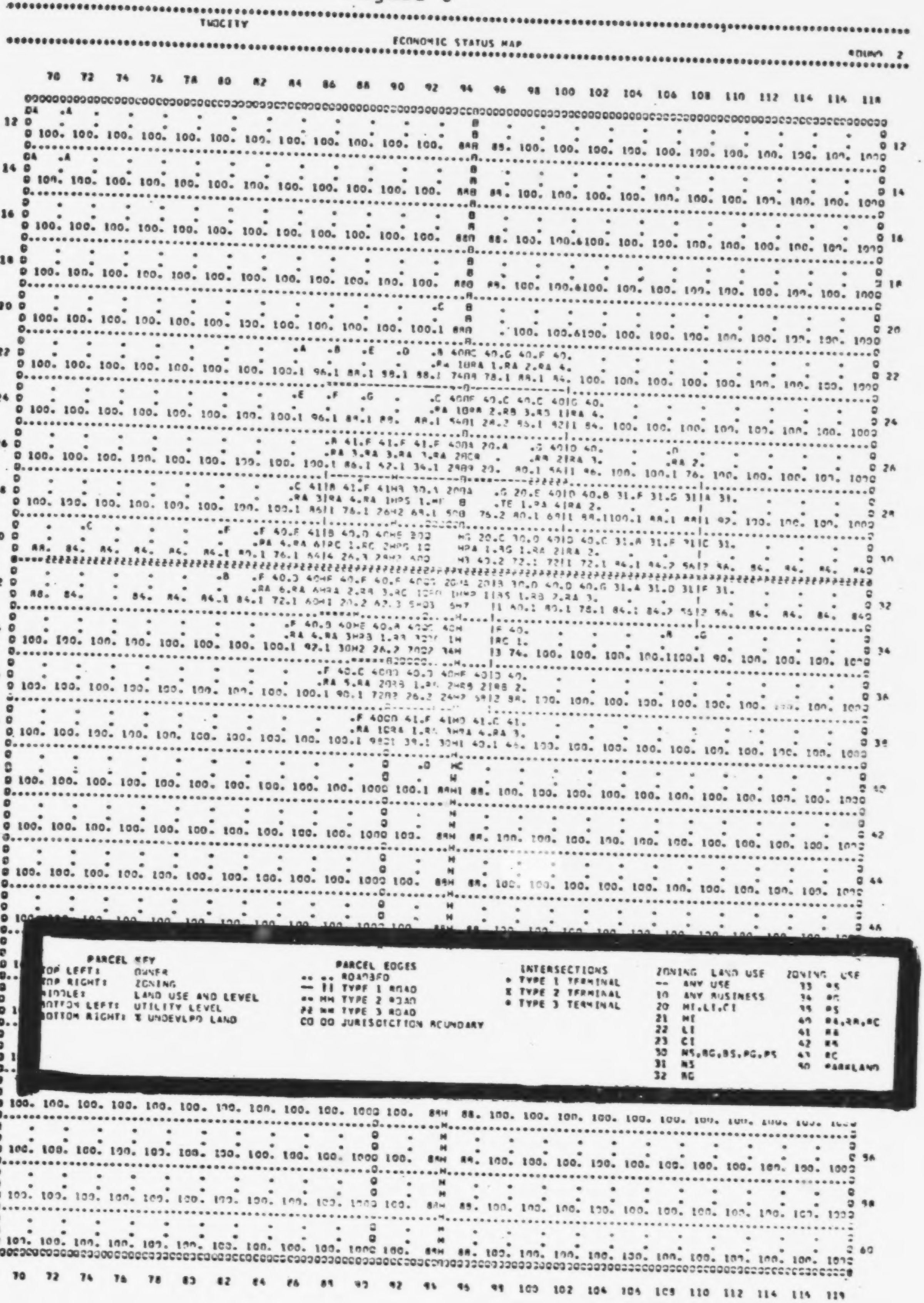
Of the dozens of maps, the Economic Status Map (Figure 6) stands out as the one of single most importance. Any represented area may be defined by spatially locating land use activity, the highway network and the water system in any desired pattern on the grid map. Although this map does not show the local water system, there are a number of maps that do.

All physical objects (industries, stores, housing, schools, government facilities, roads, rivers, and treatment plants) are located in a specified section of the regional area. Most facilities are located on parcels of land (identified by two even coordinate numbers). Roads are loacted (conceptually) along the boundaries (sides) of the square land parcels (identified by an even-odd or odd-even number). A road on the map actually represents all the major and minor roads that connect an origin and a destination at each end of the transportation link. Transportation terminals are located at the corners of parcels (identified by two odd-numbered coordinates).

Other local system phenomena are also spatially located. Population units are housed in residences on parcels, service districts and farms are defined in terms of contiguous parcels. Figure 7 is a list of the map output separated into ten categories.

Preceding page blank

Figure 6


TWOCITY
ECONOMIC STATUS MAP
ROUND 2
PARCEL KEY
TOP LEFT: OWNER
TOP RIGHT: ZONING
MIDDLE: LAND USE AND LEVEL
BOTTOM LEFT: UTILITY LEVEL
BOTTOM RIGHT: % UNDEVLPD LAND
PARCEL EDGES
-- .. ROADBED
— II TYPE 1 ROAD
== HH TYPE 2 ROAD
## TYPE 3 ROAD
CC OO JURISDICTION BOUNDARY
INTERSECTIONS
• TYPE 1 TERMINAL
X TYPE 2 TERMINAL
• TYPE 3 TERMINAL
ZONING LAND USE
-- ANY USE
10 ANY BUSINESS
20 HI,LI,CI
21 HI
22 LI
23 CI
30 RS,RG,BS,PG,PS
31 RS
32 RG
ZONING USE
33 BS
34 PG
35 PS
40 RA,RB,RC
41 RA
42 RB
43 RC
50 PARKLAND

Reproduced from best available copy.

Figure 7

MAP OUTPUT

Map Category	Map Number	Map Name
Commercial	10.1	Personal Goods Allocation Map
	10.2	Personal Services Allocation Map
	10.3	Business Commercial Allocation Map
Government Service	10.4	Municipal Service Map
	10.5	School Map
	10.6	Utility Map
Water System	10.7	Water Usage Map
	10.8	Water Quality Map
	10.9	Municipal Treatment
	10.10	Municipal Intake and Outflow Point Map
	10.11	Surface Water Map
	10.12	Farm Runoff Map
	10.13	River Basin Flood Plain Map
Farms	10.14	Farm Map
Property Values	10.15	Farm Assessed and Market Value Map
	10.16	Market Value Map
	10.17	Assessed Value Map
Land Use and Regulations	10.18	Economic Status Map
	10.19	Highway Map
	10.20	Planning and Zoning Map
Parks	10.21	Parkland Usage Map
Social Characteristics	10.22	Socio-Economic Distribution Map
	10.23	Demographic Map
	10.24	Social Decision-Maker Map
Physical Characteristics	10.25	Topographical Restriction Map
Government Facilities	10.26	Government Status Map

Tabular Computer Output

The economic, social, and government teams receive computer output that describes the details of the resources over which they have decision-making power. In addition to this team-specific information, general and summary statistics describing the represented area are available as common information to all teams. A list of all the tabular output is shown in Figure 8.

To provide examples of the tabular output, the following descriptions of migration and the water system are provided.

1. Migration - The basic population grouping in the model is the population unit (Pl). A Pl is designated as being a member of a socio-economic class (H, M, or L).

Pl's move into, within, and out of the local system in response to available employment opportunities, housing quantity and quality, and a number of other factors. Figure 9 shows a sample of the summary migration statistics for an area and a portion of the detailed statistics.

The Migration-Housing computer routine calculates dissatisfaction (environmental and personal); develops a pool of movers comprised of the population displaced by housing demolition, a percent of the most dissatisfied, a percent of the total population (random movers), natural population growth, and the in-migrants; and moves the members of this pool into housing that has adequate capacity and quality.

A certain percentage of each income class that are either unemployed or underemployed outmigrate from the local system. Other movers who cannot find adequate local housing also become outmigrants.

Referring to Figure 9, the Pl's living in the residences (or considering to live in the residences) on parcel 9422 see a health index of 50 (the higher the index the worse the situation). The time indexes are calculated only for the income classes actually living on the parcel. For example, on parcel 9422 there were PM groups living there and because of the distance and mode used to travel to work, 25 units of dissatisfaction were added to the personal index. Another 59 units were added to the index because of the amount of leisure time that was spent in involuntary pursuits.

Figure 8

TABULAR OUTPUT

Output Category	Code Number	Output Name
Migration	1.1	Environmental Indexes
	1.2	Personal Indexes
	1.3	Dissatisfaction Cutoffs
	1.4	Migration Detail
	1.5	Migration Statistics
	1.6	Migration Summary
Water System	2.1	Water User Effluent Content
	2.2	River Quality During Surface Water Process
	2.3	Water User Costs and Consumption
	2.4	Coliform and Pollution Index Values
Employment	3.1	Employment Selection Information for PL Class
	3.2	Employment Selection Information for PM Class
	3.3	Employment Selection Information for PH Class
	3.4	Part-Time Work Allocation for PH Class
	3.5	Part-Time Work Allocation for PM Class
	3.6	Part-Time Work Allocation for PL Class
	3.7	Employment Summary
Commercial Allocation	4.1	Personal Goods Allocation Summary
	4.2	Personal Services Allocation Summary
	4.3	Business Goods Allocation Summary
	4.4	Business Services Allocation Summary
	4.5	Government Contracts
	4.6	Terminal Demand and Supply Table
	4.7	Terminal Allocation Map
Social Sector	5.1	Dollar Value of Time
	5.2	Social Decision-Maker Output
	5.3	Social Boycotts
Economic Sector	6.1	Farm Output
	6.2	Residence Output
	6.3	Basic Industry Output
	6.4	Commercial Output
	6.5	Economic Boycott Status
	6.6	New Construction Table
	6.7	Land Summary
	6.8	Loan Statement
	6.9	Financial Summary
Social and Economic Summaries	7.1	Number of Levels of Economic Activity Controlled by Teams
	7.2	Employment Centers
	7.3	Economic Control Summary for Teams
	7.4	Social Control Summary for Teams
	7.5	Social Control Summary Totals
	7.6	Economic Graphs for Teams
	7.7	Social Graphs for Teams

Government Detail	8.1	Assessment Report
	8.2	Water Department Reports
	8.3	Sampling Station Report: Point Source Quality
	8.4	Sampling Station Report: Ambient Quality
	8.5	Utility Department Report
	8.6	Utility Department Finances
	8.7	Municipal Services Department Report
	8.8	Municipal Services Department Finances
	8.9	Municipal Services Department Construction Table
	8.10	Planning and Zoning Department Report
	8.11	School Department Report
	8.12	School Department Finances
	8.13	School Department Construction Table
	8.14	Highway Department Finances
	8.15	Highway Department Construction Table
	8.16	Rail Company Report
	8.17	Bus Company Report
	8.18	Chairman Department Finances
	8.19	Tax Summary
	8.20	Financial Summary
Summary Statistics	9.1	Demographic and Economic Statistics

Figure 9

```
                  TWOCITY
            PERSONAL INDEXES
*****************************************************************************************************ROUND  2

                        HEALTH INDEX
               ------------------------------------
                          CROWDING  BACTERIA                         TRANSP.          INVOL.    PERSONAL
  LOCATION     MS EFFECT  EFFECT    EFFECT     TOTAL      CLASS      TIME     RECR.   TIME      INDEX
  --------     ---------  --------  --------   -----      -----      -------  -----   ------    --------

    9422           25        25         0        50       LOW           0       0       0          50
                                                          MIDDLE       25       0      59         134
                                                          HIGH          0       0       0          50

    9622           25         0         0        25       LOW          25       0      76         126

*****************************************************************************************************
                  TWOCITY
            ENVIRONMENTAL INDEXES                                                             ROUND  2
*****************************************************************************************************

                                            NEIGHBORHOOD INDEX
                             ---------------------------------------------------------
               POLLUTION             RESIDENCE                           WELFARE               ENVIRONMENTAL
  LOCATION     INDEX         CLASS   QUALITY     RENT  MS   SCHOOL    OR TAXES    TOTAL           INDEX
  --------     ---------     -----   ---------   ----  --   ------    --------    -----        -----------

    9422           0         LOW        19         0  100     0           12       131             131
                             MIDDLE     39         0  100     0           24       163             163
                             HIGH       49         0  100     0           24       173             173

    9622           0         LOW        44         0  100     0           16       160             160
                             MIDDLE     64         0  100     0           18       182             182
                             HIGH       74         0  100     0           18       192             192

*****************************************************************************************************
                  TWOCITY
            MIGRATION DETAIL                                                                  ROUND  2
*****************************************************************************************************

                          SOCIAL    NUMBER
                          DECISION  OF                  QUALITY OF    NUMBER                  FROM/TO    REASON FOR
PARCEL  OWNER  TYPE       MAKER     PI'S     CLASS      LIFE          MOVED                   PARCEL     MOVING            EMPLOYER
------  -----  ----       --------  ------   -----      ----------    ------                  -------    --------------    --------

 9422     G    RA 1          F        1      LOW          181             1  CAME FROM        10030     DISPLACEMENT        9828

                             C        1      MIDDLE       297             1  WENT TO           9636     DISSATISFACTION     9626

 9622     D    RA 1          D        2      LOW          286

MIGRATION DUE TO PERSONAL DISSAT.
                LOW CLASS                                MIDDLE CLASS                                  HIGH CLASS
FROM/TO  JUR-1  JUR-2  JUR-3  OUTSIDE        FROM/TO  JUR-1  JUR-2  JUR-3  OUTSIDE        FROM/TO  JUR-1  JUR-2  JUR-3  OUTSIDE
JUR-1      0      0      0      0            JUR-1      6      2      0      4            JUR-1     16      6      0     11
JUR-2      5     14      0     10            JUR-2      0      0      0      0            JUR-2      0      0      0      0
JUR-3      0      0      0      0            JUR-3      0      0      0      0            JUR-3      0      0      0      0
OUTSIDE    0      0      0      0            OUTSIDE    0      0      0      0            OUTSIDE    0      0      0      0
```

12

Note that there are six items that comprise the environmental index and their contributions to that index are listed in the output. The number of population units that move to and from each residential parcel and their reasons for moving are also shown in the output.

The purpose of showing Figure 9 is not to explain how the migration process works but to illustrate that the full results of the process are illustrated on tabular computer output that can be of great assistance to the users of the model in their decision-making.

2. The Water System - Figure 10 shows some tabular computer output for a local system river (River 2). This output shows the location of each segment of the river, the quality rating and major pollutant, the time period in the water's passage through a parcel, the amount of each of the seven pollutant types, and the volume of the water.

Once again, it is not important that the reader fully understand this information at this time. It is illustrated here only for the purpose of showing the type of tabular computer output generated each round as part of the model operation.

Indicators

The model output is also expressed in some instances by indicators. Major indicators in the economic sector are net worth for teams and rates of return on individual investments. Major indicators in the social sector are the per capita personal incomes and the quality of life indexes. Major government indicators are the service use indexes for schools, parks, and municipal services and congestion of highways. Major indicators in the local water system are the water quality ratings.

Figure 11 shows the average quality of life index for the population units (by class) controlled by a social team. Figure 12 shows the Water Quality Map for TWO CITY in Round 2.

The River Basin Model As A Set Of Regional Accounts

Since the River Basin Model is a model of an entire regional system, there is the requirement that accounts balance within the local system. For example, every expenditure for one activity is an income for another activity. Similarly, local sales and income from services rendered are actually

Figure 10

```
**************************************************************************************************************
                              TRICITY
                    RIVER QUALITY DURING SURFACE WATER PROCESS:   RIVER  2                          ROUND  2
**************************************************************************************************************

                                                  BOD      CHLORIDES   NUTRIENTS    COLIFORM   TEMPERATURE  AGE OF  AGE OF   AMOUNT
LOCATION  QUALITY          TIME                (X 100)     (X 100)     (X 100)     (X 100)     (X 100)      OFS     HLW    (MGDX100)
--------  -------   ------------------------  ---------  ----------  ----------  ----------  -----------  ------  ------  ---------


  9630      10      FROM OTHER PARCELS            12118        3297      213962          22            0      0       0       49700

  9630      10      AFTER AGING                   12118        3297      213962          22            0      0       0       50000
  9630      10      BEFORE BIO CHANGE              5662        1540       98963          10            0      0       0       21360
  9630      10      AFTER BIO CHANGE               5404        1385       93934           9            0      0       0       21360
  9630      72      EFFLUENT ADDED               999072     1265412    29970018           4            0      0       0       26640
  9630      63      MOVED TO NEXT PARCEL        1004476     1266797    30063952          13            0      0       0.      50300

  9632      63      AFTER AGING                 1004476     1266797    30063952          13            0      0       0       51000
  9632      63      BEFORE BIO CHANGE            561325      707916    16800632           7            0      0       0       28500
  9632      63      AFTER BIO CHANGE             535810      637124    15782224           6            0      0       0       28500
  9632      92      EFFLUENT ADDED              4500016     1912502     5625007        4500       135000      0       0       22500
  9632      72      MOVED TO NEXT PARCEL        5035826     2549626    21407231        4506       135000      0       0       51000

  9432      72      AFTER AGING                 5035826     2549626    21407231        4506       135000      0       0       52000
  9432      72      BEFORE BIO CHANGE           4561296     2309372    19389984        4081       122279      0       0       47100
  9432      72      AFTER BIO CHANGE            4353964     2078434    18214832        3771            0      0       0       47100
  9432      91      EFFLUENT ADDED             14719873     1980107    49059846       14702        66100      0       0        4961
  9432      91      MOVED TO NEXT PARCEL       19073837     4058541    67274678       18473        66100      0       0       52000

  9232      91      AFTER AGING                19073837     4058541    67274678       18473        66100      0       0       53000
  9232      91      BEFORE BIO CHANGE          19073837     4058541    67274678       18473        66100      0       0       53000
  9232      91      AFTER BIO CHANGE           18206832     3652686    63197216       17073            0      0       0       53000
  9232       0      EFFLUENT ADDED                    0           0           0           0            0      0       0           0
  9232      91      MOVED TO NEXT PARCEL       18206832     3652686    63197216       17073            0      0       0       53000

  9032      91      AFTER AGING                18206832     3652686    63197216       17073            0      0       0       54000
  9032      91      BEFORE BIO CHANGE          18206832     3652686    63197216       17073            0      0       0       54000
  9032      91      AFTER BIO CHANGE           17379248     3287417    59367072       15779            0      0       0       54000
  9032       0      EFFLUENT ADDED                    0           0           0           0            0      0       0           0
  9032      91      MOVED TO NEXT PARCEL       17379248     3287417    59367072       15779            0      0       0       54000

  8832      91      AFTER AGING                17379248     3287417    59367072       15779            0      0       0       55000
  8832      91      BEFORE BIO CHANGE          17379248     3287417    59367072       15779            0      0       0       55000
  8832      91      AFTER BIO CHANGE           16589283     2958675    55769056       14583            0      0       0       55000
  8832       0      EFFLUENT ADDED                    0           0           0           0            0      0       0           0
  8832      91      MOVED TO NEXT PARCEL       16589283     2958675    55769056       14583            0      0       0       55000

  8632      81      AFTER AGING                16589283     2958675    55769056       14583            0      0       0       56000
  8632      81      BEFORE BIO CHANGE          16589283     2958675    55769056       14583            0      0       0       56000
  8632      81      AFTER BIO CHANGE           15835224     2662807    52389104       13478            0      0       0       56000
  8632       0      EFFLUENT ADDED                    0           0           0           0            0      0       0           0
  8632      81      MOVED TO NEXT PARCEL       15835224     2662807    52389104       13478            0      0       0       56000

  8432      81      AFTER AGING                15835224     2662807    52389104       13478            0      0       0       57000
  8432      81      BEFORE BIO CHANGE          15835224     2662807    52389104       13478            0      0       0       57000
  8432      81      AFTER BIO CHANGE           15115441     2396526    49214000       12456            0      0       0       57000
  8432       0      EFFLUENT ADDED                    0           0           0           0            0      0       0           0
  8432      81      MOVED TO NEXT PARCEL       15115441     2396526    49214000       12456            0      0       0       57000

  8232      81      AFTER AGING                15115441     2396526    49214000       12456            0      0       0       58000
  8232      81      BEFORE BIO CHANGE          15115441     2396526    49214000       12456            0      0       0       58000
  8232      81      AFTER BIO CHANGE           14428375     2156873    46231328       11512            0      0       0       58000
  8232       0      EFFLUENT ADDED                    0           0           0           0            0      0       0           0
  8232      81      MOVED TO NEXT PARCEL       14428375     2156873    46231328       11512            0      0       0       58000

  8032      81      AFTER AGING                14428375     2156873    46231328       11512            0      0       0       59000
  8032      81      BEFORE BIO CHANGE          14428375     2156873    46231328       11512            0      0       0       59000
  8032      81      AFTER BIO CHANGE           13772539     1941185    43429424       10639            0      0       0       59000
  8032      23      EFFLUENT ADDED                    0           0       96000           0            0      0       0        3330
  8032      81      MOVED TO NEXT PARCEL       13772539     1941185    43525424       10639            0      0       0       59000

  7832      81      AFTER AGING                13772539     1941185    43525424       10639            0      0       0       60000
  7832      81      BEFORE BIO CHANGE          13772539     1941185    43525424       10639            0      0       0       60000
  7832      81      AFTER BIO CHANGE           13146514     1747066    40887520        9833            0      0       0       60000
  7832      67      EFFLUENT ADDED                   35          36       96037          38           15      6       0        3001
  7832      81      MOVED TO NEXT PARCEL       13146549     1747102    40983557        9871           15      6       0       60000

  7632      81      AFTER AGING                13146549     1747102    40983557        9871           15      0       0       61000
  7632      81      BEFORE BIO CHANGE          13146549     1747102    40983557        9871           15      0       0       61000
  7632      81      AFTER BIO CHANGE           12548978     1572391    38499696        9123            0      0       0       61000
  7632      23      EFFLUENT ADDED                    0           0       96000           0            0      0       0        3330
  7632      81      MOVED TO NEXT PARCEL       12548978     1572391    38595696        9123            0      0       0       61000

  7432      81      AFTER AGING                12548978     1572391    38595696        9123            0      0       0       62000
  7432      81      BEFORE BIO CHANGE          12548978     1572391    38595696        9123            0      0       0       62000
  7432      81      AFTER BIO CHANGE           11978569     1415151    36256560        8631            0      0       0       62000
  7432       0      EFFLUENT ADDED                    0           0           0           0            0      0       0           0
  7432      81      MOVED TO NEXT PARCEL       11978569     1415151    36256560        8631            0      0       0       62000
```

Figure 11

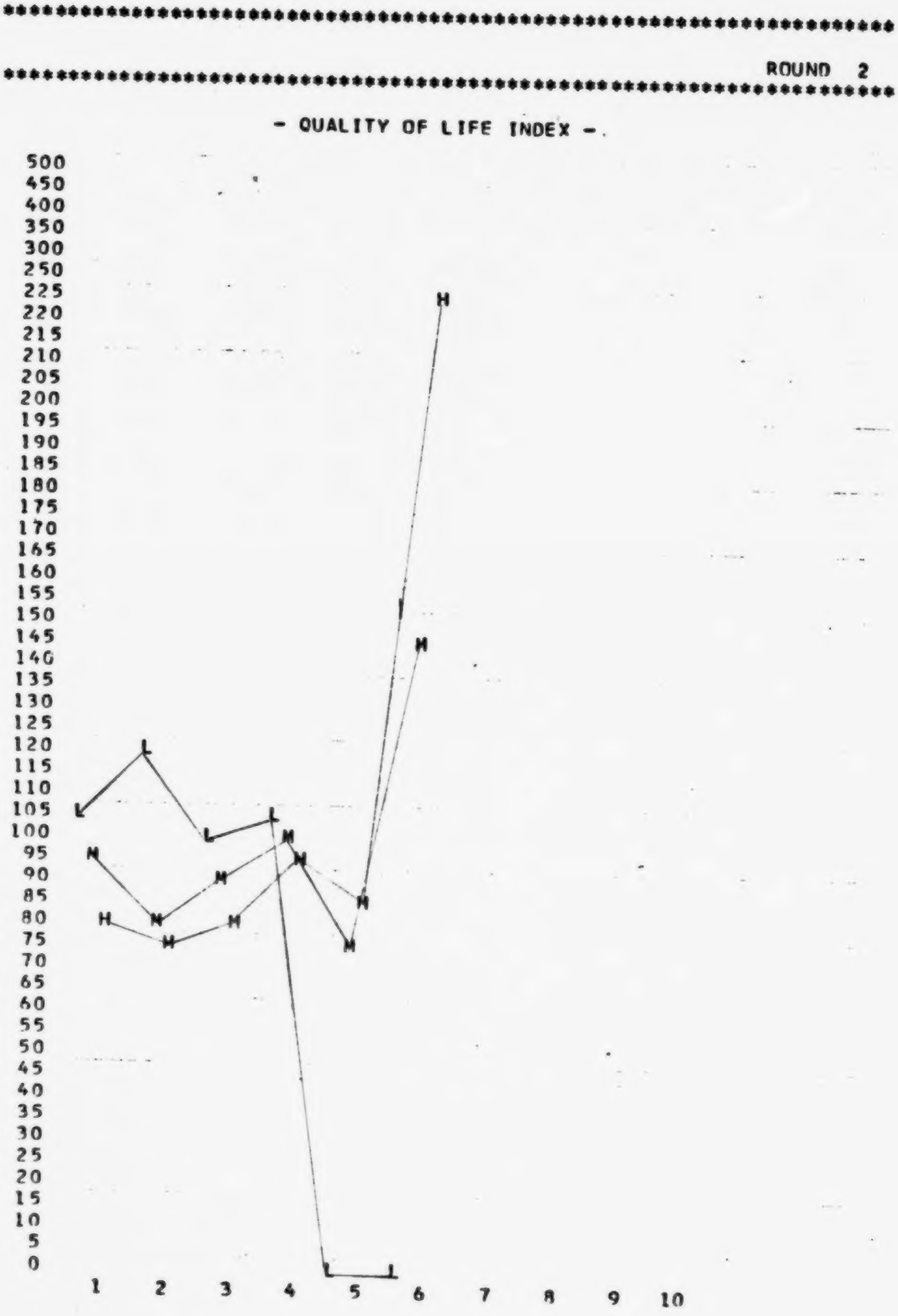
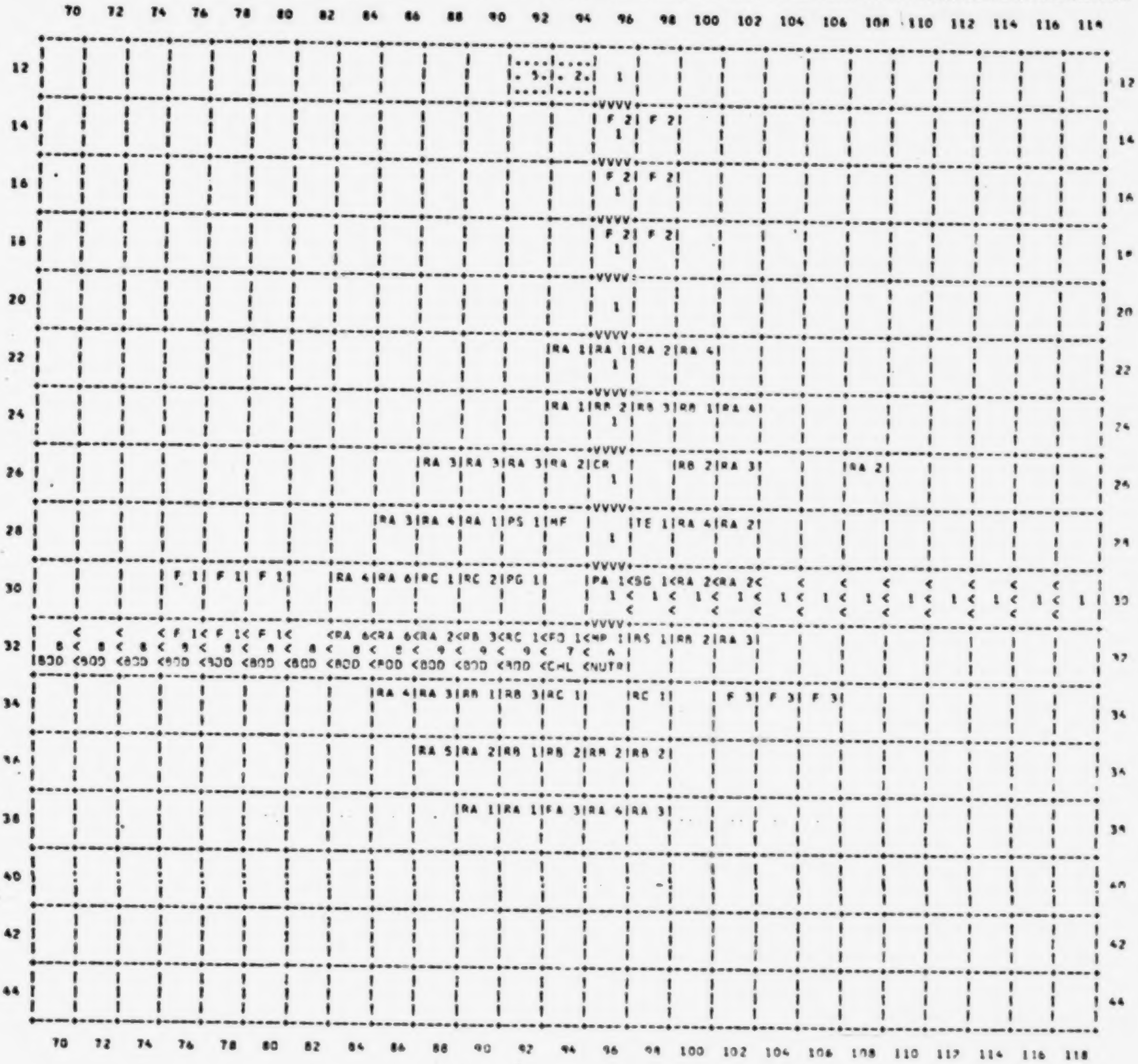

ROUND 2
- QUALITY OF LIFE INDEX -
500
450
400
350
300
250
225
220
215
210
205
200
195
190
185
180
175
170
165
160
155
150
145
140
135
130
125
120
115
110
105
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
L
H
M

Figure 12

```
*****************************************************************************
                    TWOCITY
                    WATER QUALITY MAP
*****************************************************************************
                                                                    ROUND  2
```



```
PARCELS
-------
    TOP ROW: ECONOMIC ACTIVITY TYPE                  PARCEL EDGES
             AND OPERATING LEVEL                     ------------
             FARM TYPE IF FARM ON PARCEL             >AV<  DIRECTION OF FLOW
MIDDLE ROW: SURFACE WATER QUALITY RATING
BOTTOM ROW: WORST POLLUTANT                          ----  NO WATER FLOWING
                                                           BETWEEN PARCELS

....
....  LAKE PARCELS
....
```

derived by totaling the expenditures made by the P1's or business activities for these goods and/or services. Therefore, the impact of water quality and cost decisions on the financial accounts for various population and business groups and by location can be followed over time. Not only are water usage figures calculated, but also expenditures for water, pollution treatment and fines. In short, the River Basin Model is a systems accounting framework as well as an integration of many market models within a spatial context.

SECTION VII

MODEL INPUTS

Three types of model inputs should be distinguished: initial director inputs, player inputs, and continual director inputs.

Initial Director Inputs

Some of the initial director inputs were discussed under the chapter on users of the model. Briefly, he can choose a prespecified (two at this time) starting configuration. With this configuration he may make any number of changes to alter the starting scenario. Or, he can load into the computer a starting configuration that he has fashioned out of real or hypothetical data.

The initial starting position of the model is very flexible in several ways. First, any desired initial land use pattern may be represented. Thus, a model run could begin with development ranging from a blank board to a fully occupied land area. Also, from one to fifteen separate local governments can be represented.

Second, the population classes placed into housing, rents charged at housing, prices charged at stores, salaries offered by employers, taxes charged by local governments, etc. can be set in an infinite number of patterns. For example, the five population classes could be distributed among the housing stock in such a way that there was much or little income segregation, overcrowding or under-occupancy, etc. Or any transportation subsystem configuration could be represented.

Third, the control over the economic, social, and governmental resources of the represented area can be allocated among users of the model in any way desired. For example, if a single person were using the model for research or simulation purposes, all of the economic assets could be placed under the control of a single corporation. If the model is being used for citizen participation or educational purposes, the director of the model might choose to have the resources of the community allocated in such a way that some corporations own only one type of economic activity (industry, commercial establishments, residences, or land) or several types of activities (a mix of industrial, commercial, residential, and vacant land).

The economic, social, and government sector computer output describes the details of the resources in these sectors. In addition to this specific information, general and summary statistics describing the represented area are available as information common to all the model users.

Model users provide the evaluation of the status of the area as a whole and of the individual sector resources in particular, develop goals and objectives, formulate strategies, and make decisions for the coming calendar year. All the information on the computer print-outs describes the represented area at one point in the year. All decisions that are made take effect at that time and their impact is not seen until the decisions are processed through the computer and a new status is generated for the next year.

A subset of the initial director decisions are those that relate to the local water system. The director through the load program may create a region that has any mix of water quantity and quality characteristics. For example, a region could be configured that had very low quality water and no treatment facilities at the start of play. Or an initial starting point could be developed that had all the pollution created by activities in one jurisdiction have its major detrimental effects on activities and people in a downstream jurisdiction.

Player Inputs

Players have available to them a wide number of possible formal decisions (ones that require processing by the computer) and they have an infinite number of informal decision options open to them. The formal decisions available to the players are summarized in Figure 13 under the three sector headings.

A subset of the player decisions are those that relate to the local water system. Economic decision-makers may build waste treatment facilities for their industries that dump into the local water system. They may also cut back operating levels of businesses in order to reduce the pollution they generate. These two decisions do not fully indicate the impact that the water component has or may have on the specific sections of the local system because of inadequate water supply, high municipal water costs, poor surface water quality, poor transportation access caused by the absence of bridges to cross a river, etc.

Figure 13

1. Economic Decision-Makers

   - buy and sell land
   - set rents
   - set prices
   - set salaries
   - set maintenance levels
   - lend money
   - borrow money
   - buy and sell conservative stocks
   - buy and sell speculative stocks
   - build and demolish three types of residences, twelve types of basic industries, and four types of commercial establishments
   - contract with construction industries
   - transfer money to other economic and social and government decision-makers
   - boycott commercial establishments
   - construct chlorination, primary, secondary and tertiary effluent treatment facilities at basic industries
   - change the operating level of a business (without demolishing the building)
   - set the amount of water which is recycled at basic industries
   - construct residences which use ground water
   - operate farms

2. Social Decision-Makers

   - allocate time to extra work, education, politics and recreation
   - boycott work locations, commercial establishments, and modes of travel
   - vote for elected officials
   - set the dollar value of time travelling to work
   - transfer money to other social, economic and government decision-makers

3. Government Decision-Makers

   - grant appropriations
   - grant subsidies
   - transfer money to other government and social and economic decision-makers
   - set welfare payments
   - set tax rates
   - float bonds

Figure 13 (Cont.)

- assess land and buildings
- buy and sell land
- set the number of job openings in government
- set the maintenance level of government facilities
- set government service districts
- request Federal-State aid
- set the salaries offered government workers
- build and demolish schools
- build and demolish municipal service plants
- contract with construction industries
- grant contracts with local goods and services establishments for government purchases
- set the amount of public adult education offered by the government
- construct and demolish roads
- construct and demolish terminals
- zone land
- build and demolish public institutional land uses
- provide parkland
- install utility service
- set prices for utility service
- construct and demolish utility plants
- locate bus routes
- buy and sell buses
- set bus and rail fares
- build rail lines
- build rail stations
- buy and sell rail rolling stock
- locate rapid rail routes
- set the amount of service on bus and rail routes
- set prices for private use of publicly-provided water
- construct and demolish primary, secondary, and tertiary sewage treatment plants
- construct and demolish water intake treatment plants
- locate municipal water intake points
- locate municipal sewage outflow points
- locate water sampling stations
- set dam priorities
- change a business's operating level (without demolishing the building)
- construct and demolish bridges across rivers

Social sector decision-makers may be very much affected by the quantity and quality of water in the local system, but they make no direct water decisions. They do vote for elected officials, however, and to the extent that water issues are an important local concern, the social sector might influence water resource decision-making a great deal indirectly through the ballot box. These votes might be for water related referenda as well as for political officers.

The Utility Department in each jurisdiction (through its Water Office) has a number of decisions that it may make. It sets the price of municipal water for different types of buyers. It may construct intake and outflow treatment plants and locate them to best advantage taking into account water supply and quality, downstream activities, land costs, and local sentiment. It may choose where in the local water system to remove water for public consumption and where to dump the municipal wastes.

Furthermore, the water resources decision-maker may fund and locate sampling stations (ambient or point source) and set dam operating priorities (to favor recreation, flood control, and/or pollution control). Other government departments compete with the Utility Department for local citizen support and possibly for outside government financial assistance. The Highway Department is affected directly by the local water system in that it costs more to put highways across parcels that contain rivers. This higher cost represents the added expense of building bridges and tunnels.

Figure 14 shows an example of a completed team decision form and the computer "Edits" of a set of decisions for a round of the model. Since collectively the teams comprise most of the major local decision-makers of the represented area, most of the change that will take place from one round to the next will be a function of the number and type of decisions generated by the teams. The major decisions not made by the teams are those made either by computer simulators which represent the outside system impacts on the local system or by the director who may act as higher level governments or as Mother Nature and cause floods, earthquakes, and/or other forms of natural disaster.

Teams will often note that the decisions of other teams have significant effect on their own output, especially on the indicators. For example, the water quality rating for a particular section of the river might increase tremendously because of the creation of more housing with no increase in the

Figure 14

SAMPLE OF INPUTS AND EDITS

INPUTS

Decision Code	Decision-Maker	a	b	c	d	e	f	g	h	i
$ 0UBLD /	= A /	7012,	RB,	0,	1,	50,	60,	0,	145,	
$ 0UBLD /	= E /	8430,	RA,	6,	4,	,	,	,	,	
$ FSA /	= SC1 /	2,	9030,	,	,	,	,	,	,	
$ FSA /	= SC1 /	1,	10812,	,	,	,	,	,	,	
$ TIME /	= BB /	H2,	20,	0,	15,	5,	5,	,	,	
$ /	= /	,	,	,	,	,	,	,	,	

EDITS

```
$OUBLD/=A/7012,RB,0,1,50,60,0,145*    NO UTILITIES
REQUIRES LEVEL 1 UTILITY SERVICE ONLY HAS LEVEL 0

$OUBLD/=F/8430,RA,6,4*

$FSA/=SC1/2,9030*
AID REQUEST OF SC1 FOR  9030 GRANTED
```

municipal treatment facilities. Rates of return might drop because of increased local tax rates or assessments, higher maintenance costs or service charges, increased competition, etc. Or housing dissatisfaction might increase because the housing stock has deteriorated, rents have gone up, or local government services have decreased in quality.

The interactions among the various components of the urban system that cause these interrelated movements of decisions and indicators is generated by several major simulations contained within the computer program of the model. The model is indifferent as to how the inputs are generated. That is, the inputs could be generated as a result of a game format or by a single model user. The game format could be capitalistic and democratic in nature or socialistic.

Periodic Director Inputs

The director may act as the outside system by controlling land purchases, loans, cash transfers, exogenous employment, federal aid, the business cycle, and the effects of Mother Nature. These effects on the local system require computer inputs on the part of the director. A number of other influences he may exert on the local system and its decision-makers are handled in the gameroom and need no interface with the computer. For example, the director could impose higher government regulations on the local system in the form of water quality standards, school quality, or municipal service standards. The director could also change player assignments (switch players among several teams), make some computer information inaccessible (or acquired only at high cost), prevent or encourage team interaction by their physical placement in the gameroom, require rounds to be played in a specified amount of real clock time, or a number of other things.

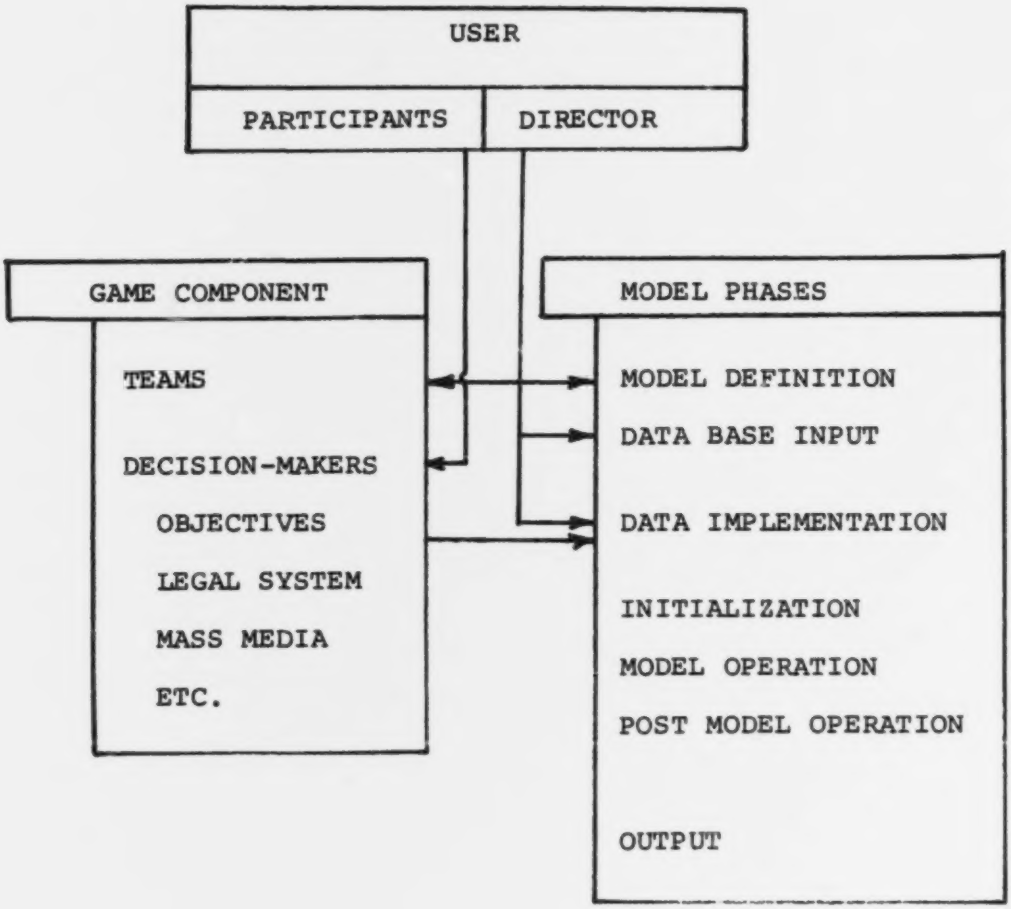
Each director will find that he can affect the play a great deal and force the local system to deal with problems created by him if he wishes to exercise some of these director options. On the other hand, the director is not forced to make any of these periodic inputs. The model will continue to function without his use of these prerogative director decisions.

Summary

Figure 15 summarizes the user inputs to the model. This figure shows the interaction of the user (as director or participant) of the model with the game component and with the phases of the model. First, as part of "Model Definition" the director has the option to define parts of the model

Figure 15

INTERACTION BETWEEN THE USER AND THE RIVER BASIN MODEL


USER
PARTICIPANTS
DIRECTOR
GAME COMPONENT
TEAMS
DECISION-MAKERS
OBJECTIVES
LEGAL SYSTEM
MASS MEDIA
ETC.
MODEL PHASES
MODEL DEFINITION
DATA BASE INPUT
DATA IMPLEMENTATION
INITIALIZATION
MODEL OPERATION
POST MODEL OPERATION
OUTPUT

(parcel size, jurisdiction boundaries, population-scale, etc.). Second, as part of the "Data Base Input" he can input two types of data -- parameter values for the operating programs (for example, coefficients for migration, typical construction costs, normal units of production for industries, etc.) and the number and location of population units and activities (for example, residences and the social class of the occupants, businesses, government buildings, roads, bodies of water, etc.).

The director makes these decisions once, and they define the starting configuration of the system to be represented. The geographical scope of the region represented by the director is a function of the parcel size and the number of parcels used to represent the system. Thus, a single county or a multi-county river basin area could be represented. The director also has the option to make no decisions and instead start with one of the two pre-specified hypothetical configurations.

As a third type of decision ("Teams"), the director may affect the game format by the allocation of resources to economic, social, and governmental decision-making bodies that are called teams. A final type of director influence is one that he may choose to exert any time during the operation of the model. By making inputs to the model (using the same input format as the participants), the director can control the outside system influences on the local system (federal-state aid, business cycle, federal regulations, etc.) and some local phenomena (flooding, federal employment, etc.).

The participants of the model are members of teams, and through the teams they become the decision-makers of the local system. As decision-makers, the participants establish individual and collective goals, create any needed institutions (such as a legal system, mass media, unions, etc.), evaluate the status of the local system and its constituent parts, and make decisions for the period of time represented by a cycle of the model (one year).

These decisions are input at the "Data Implementation" phase of the model, and they interact with one another and with the present status of the system to create a new status of the system. The new status is illustrated on the computer output, which then serves as the basis for new evaluation on the part of the decision-makers and a new cycle of game play.

SECTION VIII

EXPLANATION OF THE WATER COMPONENT

The water component can be looked at as a module that is plugged into the other major modules of the regional model. This module could be changed without changing other parts of the model (and vice versa) as long as the links among the modules were modified accordingly. Figure 16 shows the major linkages between the water module and the other modules and sectors that comprise the River Basin Model.

Water Quality Ratings

In order to summarize and simplify the concept of "water quality" in the model, an index of water quality has been created. The value of this water quality index at any location in the system is determined by the concentrations of the seven pollutant categories. Figure 17 lists the nine water quality ratings and the seven types of pollutants dealt with by the model. Note that the higher the quality rating, the lower the quality of the water.

The average quality rating of water on a parcel is calculated each round by taking the highest index caused by any of the pollutants. Figure 18 shows the water quality level generated by concentrations of each of the pollutants. An explanation of the table is also included in the figure.

Each parcel of land that contains surface water (lakes or rivers) has a water quality index calculated for it. The water quality rating for a parcel affects the treatment cost paid by users of that water. The quality rating also affects the pollution index, the rate of depreciation for some developments, the usability of the water (level 9 water is not usable), and major recreation activity. The Water Quality Map (Figure 19) shows the water quality rating for each parcel of land that has surface water, the direction of flow of rivers, the location of economic activities (including farms), and the individual pollutant responsible for the water quality rating.

Water Use and Sources of Water

All private economic activities require water as part of their normal operation. Figure 20 shows the consumption of water in millions of gallons per day (MGD) for each of these activities. Some of the manufacturing activities are surface water users, and they must intake water from the parcels on which they are located. All of the other activities use municipally supplied water (except those few residences which have private water supplies).

Preceding page blank

Figure 16

INTERACTION BETWEEN THE WATER MODULE AND OTHER PARTS OF THE RIVER BASIN MODEL

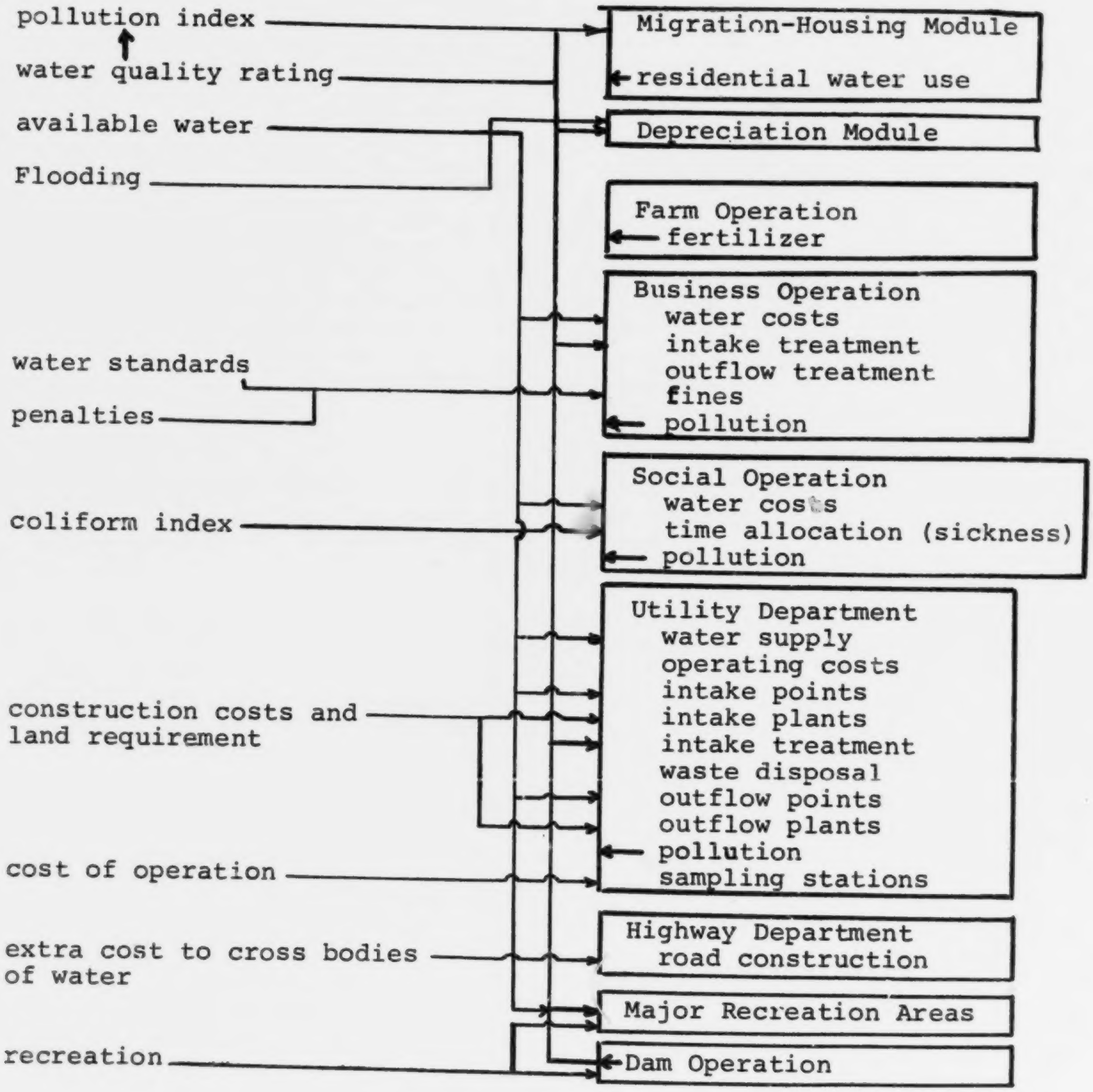

pollution index
water quality rating
available water
Flooding
water standards
penalties
coliform index
construction costs and land requirement
cost of operation
extra cost to cross bodies of water
recreation
Migration-Housing Module
residential water use
Depreciation Module
Farm Operation
fertilizer
Business Operation
water costs
intake treatment
outflow treatment
fines
pollution
Social Operation
water costs
time allocation (sickness)
pollution
Utility Department
water supply
operating costs
intake points
intake plants
intake treatment
waste disposal
outflow points
outflow plants
pollution
sampling stations
Highway Department
road construction
Major Recreation Areas
Dam Operation

Figure 17

Water Quality Rating	Description
1	Drinkable - best quality water
2	Drinkable - with minor treatment
3	Swimming - direct body contact possible
4	Boating and Fishing - indirect body contact possible
5	Fair esthetic value
6	Poor esthetic value - treatable at moderate cost
7	No esthetic value - treatable at high cost
8	Negative esthetic value - treatable at very high cost
9	Unusable water

Pollutants	Description
BOD	Biochemical Oxygen Demand
Chlorides	Chlorides are employed as an indicator of persistent pollutants.
Nutrients	Phosphate, nitrite, nitrogen, and phosphorous.
Coliform Bacteria	Indication of the potential health hazard of a given body of water.
Temperature	The temperature deviation from the normal temperature of the surface water.
Oil and Floating Solids	Any oil and all floating solids such as refuse, garbage, cans, boards, and tires.
High-Level Wastes	Highly toxic, non-degradable substances.

Figure 18

Definition of the Nine Comprehensive Water Quality Levels

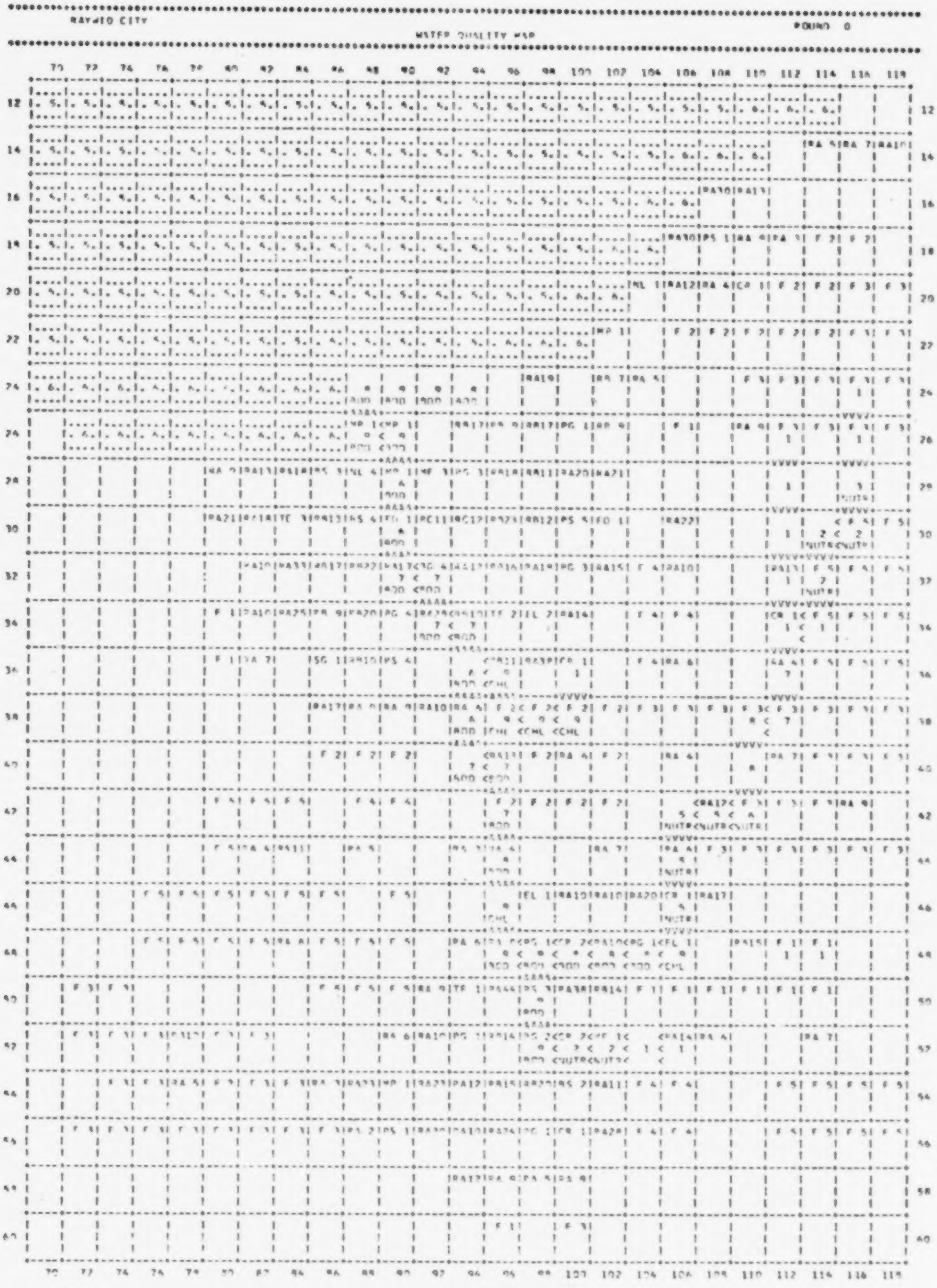
Pollutant Types	Water Quality Levels 1	2	3	4	5	6	7	8	9
BOD (LBS/MG)	10	20	30	40	60	100	150	300	> 300
Chlorides (LBS/MG)	5	10	15	20	30	40	60	80	> 80
Nutrients (LBS/MG)	25	50	100	200	400	800	1600	3200	> 3200
Coliform Bacteria (parts per MG)	2	6	12	20	40	70	120	160	> 160
Temperature	0	0	1	2	4	7	10	14	> 14
Oil & Floating Solids	0	0	0	0	0	> 0	> 0	> 0	> 0
High Level Wastes	0	0	0	0	0	0	0	> 0	> 0

Explanation of the Table

In order to determine the water quality level or index of given amounts of water, take the concentrations of each of the seven pollutant categories and calculate the water quality level based upon each pollutant separately. For example, a BOD concentration of 25 LBS/MG would yield an index of 3, coliform bacteria of 169 parts per MG would yield an index of 9, and the presence of oil and floating solids would allow the water quality to be no better than 6. The worst (highest) water quality index that was calculated using the pollutant types separately, is assigned to the given amount of water. If the water on parcel x had the three pollutants described above, it would be assigned water quality index of 9.

Looked at another way, water quality level 4 is attained when a body of water has concentrations of BOD that exceed 30 but fall below 41, coliform bacteria concentrations above 12 but below 21, etc.

Figure 19


RAYMID CITY
ROUND 0
WATER QUALITY MAP
70 72 74 76 78 80 82 84 86 88 90 92 94 96 98 100 102 104 106 108 110 112 114 116 118
12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60

PARCELS

TOP ROW: ECONOMIC ACTIVITY TYPE
AND OPERATING LEVEL
FARM TYPE IF FARM ON PARCEL
MIDDLE ROW: SURFACE WATER QUALITY RATING
BOTTOM ROW: WORST POLLUTANT
....
.... LAKE PARCELS
....

PARCEL EDGES

>AVC DIRECTION OF FLOW
---- NO WATER FLOWING
BETWEEN PARCELS

Figure 20

Figure III-5

Water Requirements For Private Economic Activities (S=Surface Water User)

Manufacturing	MGD
FL - Furniture and Lumber (S)	61
SB - Stone, Clay, and Glass	10
MP - Primary Metals (S)	225
MF - Fabricated Metals	9
NL - Nonelectrical Machinery	12
EL - Electrical Machinery	5
TE - Transportation Equipment	8
FO - Food (S)	49
TA - Textiles and Apparel (S)	17
PA - Paper (S)	333
CR - Chemical and Rubber (S)	31

Commercial	
NS - National Services	.18
BG - Business Goods	.13
BS - Business Services	.17
PG - Personal Goods	.23
PS - Personal Services	.18

Residential	
HA - High Income and Single Family	.08
HB - Garden Apartments (PH)	.07
HC - Highrise Apartments (PM)	.06
MA - Single Family (PM)	.07
MB - Garden Apartments (PM)	.05
MC - Highrise Apartments (PM)	.03
LA - Single Family (PL)	.03
LB - Garden Apartments (PL)	.03
LC - Highrise Apartments (PL)	.02

Surface water users pay for the cost of treating the water they take from the local water system. Municipal water users pay the price charged by the Utility Department. The Utility Department must construct intake facilities and treat the water if necessary to supply the water needs of each utility district.

There are four possible sources of water, although no single type of user has an option to use all of these.

Water Users

Sources	Industries Using Surface Water	Water Department	Residences	Commercial Activities & Industries Using Municipal Water
Surface Water	x	x		
Municipal Water			x	x
Outside Water	x	x	x	x
Ground Water			x	

Residents use ground water if private utilities are installed. Residences are the only activities that may satisfy their water needs through the use of wells.

Surface Water Industries and the Water Department use water from the outside system if there is an inadequate amount of water on the parcel from which they withdraw or if the water quality level is 9. Both residences and businesses using municipal water will use outside water if the water department serving them has inadequate supply.

Three types of surface water are represented in the model: rivers (flowing bodies of water), small lakes and large lakes. Large lakes are full parcels or combinations of full parcels of water. Large lakes have an unlimited volume of water and a loaded water quality level that does not change during the course of a run of the model.

Small lakes are fractions of a parcel of land. They are defined as having a specified water volume and percent of parcel consumed. Their water quality level is calcualted in the same manner as for rivers.

Rivers are loaded as being on a particular parcel, having a specific volume, flowing at a specific rate, and emptying into a designated adjacent parcel. Rivers may or may not consume a significant (one percent or more) portion of land or parcel. In other words, the land area consumed by a river may not be large enough to take into account.

All volumes are expressed in millions of gallons per day (MGD), and rates of flow are expressed in parcels of land traversed in a day by a particle of water in the river.

The following table summarizes the types of water and their characteristics.

Types of Surface Water	Volume	Water Quality Level	Rate of Flow
Rivers	Specified	Calculated	Specified
Small Lakes	Specified	Calculated	Not Applicable
Large Lakes	Unlimited	Specified	Not Applicable

Pollutants Generated

All economic activities return their used water to the local water system. Surface water users may opt to treat all or part of the water they return to the system with one of four types of treatment. The other economic activities return their water to the water system via the outflow point of the utility district in which they reside.

The specific amounts of pollution generated per level one activity and per million gallons of water for each of the types of economic activities is shown in Figure 21. Note that the pollution generated by residences is a function of both the type of housing and the income class living there.

Pollution Monitoring

The Water Office of the Utility Department may find out the detailed components of the water quality rating for any water parcel (the ambient water quality) or for any point source of water outflow (from surface water industries or from the municipal outflow point). Figure 22 shows examples of the ambient and point source sampling station reports. Note that the point source information includes the economic owner of the economic activity, the type of economic activity, and the type and level of treatment facilities, if any.

Figure 21

POLLUTION GENERATED BY ECONOMIC ACTIVITIES

Manufacturing	BOD (LBS/MG)	Chlorides (LBS/MG)	Nutrients (LBS/MG)	Coliform (PARTS/MG)	Temperature	Oil and Solids	High Level Wastes
FL	600	100	1000	20	9	1	0
SB	500	100	1000	10	0	0	0
MP	1000	170	500	20	6	1	0
MF	500	150	700	30	0	1	0
NL	400	150	100	20	0	0	0
EL	800	200	200	20	0	0	0
TE	500	180	100	30	0	0	0
FO	6000	400	10000	300	9	1	0
TA	6000	130	4000	20	18	1	1
PA	3000	380	3000	150	16	1	1
CR	2000	600	800	50	4	1	1
Commercial							
NS	100	0	0	20	0	0	0
BG	200	0	0	10	0	0	0
BS	150	0	0	15	0	0	0
PG	250	0	0	20	0	0	0
PS	100	0	0	15	0	0	0
Residential							
HA	1250	50	100	500	0	1	0
HB	1250	50	100	500	0	1	0
HC	1250	50	100	500	0	1	0
MA	1100	40	80	500	0	1	0
MB	1100	40	80	500	0	1	0
MC	1100	40	80	500	0	1	0
LA	1000	30	70	500	0	1	0
LB	1000	30	70	500	0	1	0
LC	1000	30	70	500	0	1	0

Figure 22

```
                     SAMPLING STATION REPORT: AMBIENT QUALITY
*****************************************************************************************************
                                                                                 JURISDICTION 2
*****************************************************************************************************

LOCATION     BOD      CHLORIDES   NUTRIENTS   BACTERIALS   TEMPERATURE   OIL AND    HIGH     AMOUNT OF    WATER
           (LBS/MG)   (LBS/MG)    (LBS/MG)     (PARTS       DEVIATION    FLOATING   LEVEL     WATER      QUALITY
                                               PER MG)      (DEGREES)     SOLIDS    WASTES    (MGD)      RATING
--------   --------   ---------   ---------   ----------   -----------   --------   ------   ---------   -------

  9620       0.0         0.0        10.20        0.0           0.0          NO        NO       260.00       1
  9622       0.0         0.0         9.22        0.0           0.0          NO        NO       254.00       1
  9624       0.0         0.0         7.86        0.0           0.0          NO        NO       280.00       1
  9626     106.90       53.45      861.54        0.05          0.43         NO        YES      290.00       1
  9612       0.0         0.0         0.0         0.0           0.0          NO        NO       100.00       1
  9614       0.0         0.0         6.67        0.0           0.0          NO        NO       150.00       1
  9616       0.0         0.0         9.70        0.0           0.0          NO        NO       200.00       1
  9618       0.0         0.0        11.29        0.0           0.0          NO        NO       250.00       1
  9628     131.41       50.92      799.11        0.43          0.0          YES       YES      300.00       8
  9630     424.74      135.72     1150.11        1.08         10.66         YES       YES      500.00       8
  9632     401.90      127.26     1125.40        0.98          7.45         YES       YES      510.00       9
  9432     967.50      153.13     1982.20       29.53          5.15         YES       YES      520.00       9
*****************************************************************************************************
                     TWOCITY
                     SAMPLING STATION REPORT: POINT SOURCE QUALITY
*****************************************************************************************************
                                                                                 JURISDICTION 1
*****************************************************************************************************

                      BUSINESS   TREATMENT
LOCATION    OWNER     TYPE AND   TYPE AND    VOLUME      BOD      CHLORIDES   NUTRIENTS   BACTERIALS   TEMPERATURE   OIL AND    HIGH
                       LEVEL      LEVEL       (MGD)    (LBS/MG)   (LBS/MG)    (LBS/MG)     (PARTS       DEVIATION    FLOATING   LEVEL
                                                                                           PER MG)      (DEGREES)     SOLIDS    WASTES
--------    -----     --------   ---------   ------    --------   ---------   ---------   ----------   -----------   --------   ------

  9422        B        RA 1          0        0.10     1070.00      37.00       77.00        5.00          0.0          YES        NO
  9424        C        RA 1          0        0.10     1070.00      37.00       77.00        5.00          0.0          YES        NO
  8826        B        RA 3          0        0.35     1100.00      40.00       80.00        5.00          0.0          YES        NO
  9026        E        RA 3          0        0.35     1100.00      40.00       80.00        5.00          0.0          YES        NO
  9226        E        RA 3          0        0.35     1100.00      40.00       90.00        5.00          0.0          YES        NO
  9426        E        RA 2          0        0.21     1100.00      40.00       80.00        5.00          0.0          YES        NO
  8628        C        RA 3          0        0.24     1250.00      50.00      100.00        5.00          0.0          YES        NO
  8828        B        RA 4          0        0.49     1100.00      40.00       80.00        5.00          0.0          YES        NO
  9228        B        PS 1          0        0.18      100.00       0.0         0.0        15.00          0.0          NO         NO
  9428        A        MF 0          0        0.0         0.0        0.0         0.0         0.0           0.0          NO         NO
```

Pollution Treatment

Surface water using industries and the municipal water offices may treat their water outflow to reduce its concentrations of pollutants. Figure 23 shows the effectiveness of the four types of treatment in removing the seven types of pollutants. For example, chlorination is effective against only coliform while tertiary treatment is effective against all of the pollutants.

Effects of the Water Quality Index

The Water Quality Index on a parcel of land has direct effects on the following factors.

1. Treatment costs of water withdrawn from that parcel by the Water Department.

2. Treatment cost of water withdrawn by an industrial surface water user on that parcel.

3. The amount of personal consumption emanating from Major Recreation Areas located on or near that parcel.

4. The pollution index for that parcel.

The Pollution Index is a part of the Environmental Index which is used as a basis for determining the attractiveness of a residential parcel of land for potential in-migrants. A high Pollution Index also affects the probability of population units moving away from a residential parcel.

The Health Index for a parcel of land influences the amount of money spent by population units for health services and the amount of time lost from leisure activities. It also affects the Personal Index, which in turn influences the amount of dissatisfaction experienced by population units on a parcel. The Health Index for a parcel of land is based upon the concentration of coliform bacteria in the water. This is the only case in which a single component of the water quality index is handled separately.

All of the dissatisfaction indexes and quality of life indexes are calculated in such a way that a high value indicates high dissatisfaction or low quality of life. In Figure 24 the components of the Quality of Life Index are illustrated. For each of the indexes, the corresponding dissatisfaction term is provided in parentheses.

Figure 23

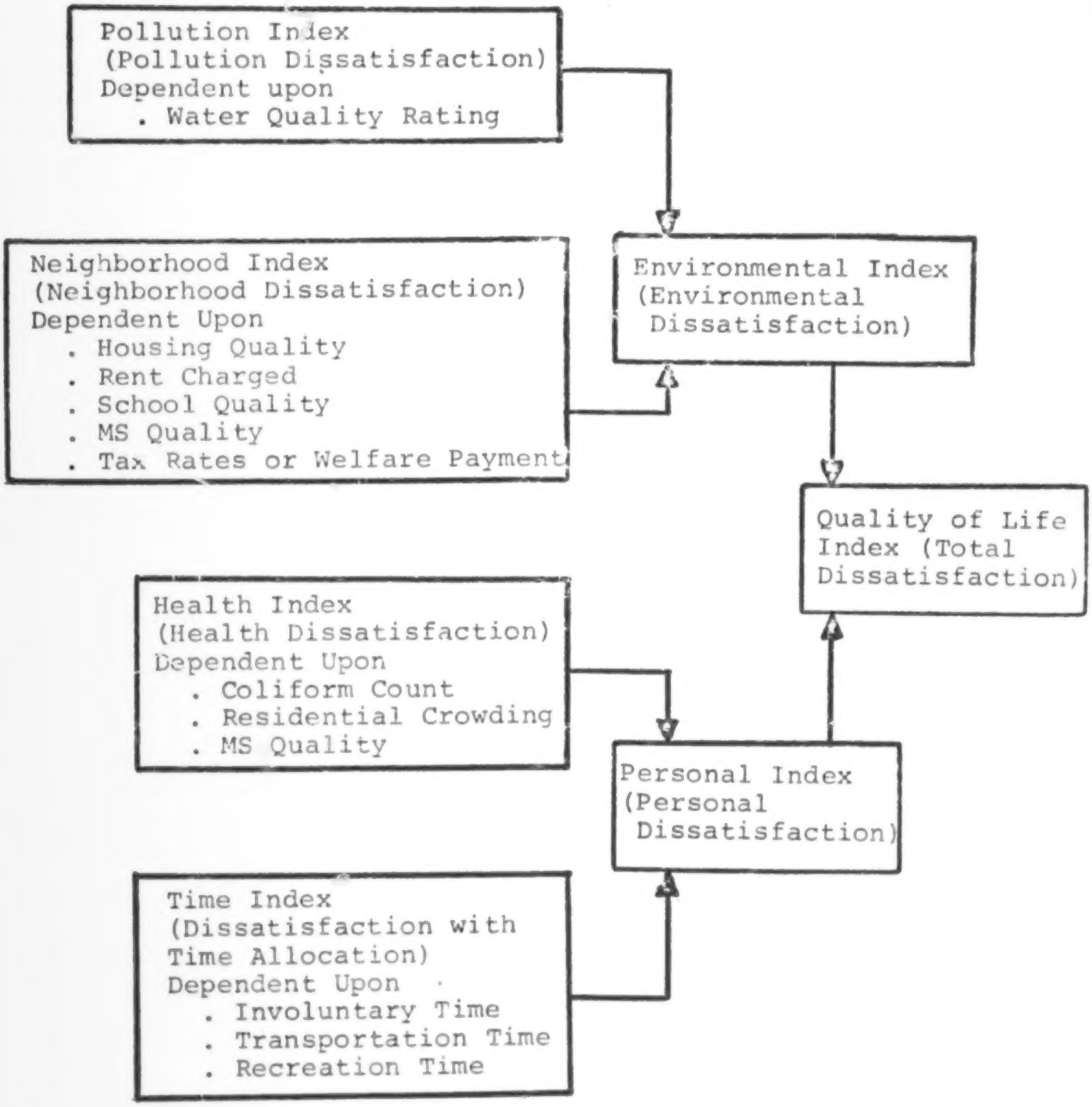
EFFECTIVENESS OF TREATMENT TYPES:

PERCENT OF POLLUTANT REMOVED

Pollutant	Chlorination (CL)	Primary (PT)	Secondary (ST)	Tertiary (TT)
BOD	-	50	80	99
Chlorides	-	-	50	90
Nutrients	-	-	20	99
Coliform	99	99	99	100
Temperature	-	-	-	100
Oil and Solids	-	100	100	100
High Level Wastes	-	-	-	100

Figure 24

COMPONENTS OF THE QUALITY OF LIFE INDEX


Pollution Index
(Pollution Dissatisfaction)
Dependent upon
. Water Quality Rating
Neighborhood Index
(Neighborhood Dissatisfaction)
Dependent Upon
. Housing Quality
. Rent Charged
. School Quality
. MS Quality
. Tax Rates or Welfare Payment
Environmental Index
(Environmental
Dissatisfaction)
Quality of Life
Index (Total
Dissatisfaction)
Health Index
(Health Dissatisfaction)
Dependent Upon
. Coliform Count
. Residential Crowding
. MS Quality
Personal Index
(Personal
Dissatisfaction)
Time Index
(Dissatisfaction with
Time Allocation)
Dependent Upon
. Involuntary Time
. Transportation Time
. Recreation Time

Note that both of the components of the Environmental Index are indexes which are based entirely upon locational quality factors outside the direct control of the social decision-makers. For example, social teams can only indirectly affect water quality, school quality and local tax rates.

The Personal Index, on the other hand, is comprised of two indices, one of which is based on locational quality factors while the other is based upon time allocation decisions that are largely within the control of the social decision-maker.

The Water and Sewer Office

The Water and Sewer Office is contained within the Utility Department, and it is charged with the responsibility of supplying the municipal water requirements within each of the utility districts. The water and sewer districts are identical to the utility districts.

The water office supplies water for a district by building a certain level of intake treatment plant on a parcel located within the same jurisdiction. The intake point does not need to be on the same parcel as the intake treatment plant. In fact, the intake point may be outside the utility district or even outside the jurisdiction. It must, however, be on a surface water parcel.

It is assumed that the cost of treating a unit of water (an MGD) is directly related to the quality level of the water. That is, it costs more to treat a unit of 8 quality water than a unit of 3 quality water.

If the total demand for municipal water within a utility district is larger than the amount that can be supplied by the intake plant, the municipal water users are obliged to purchase the needed amount of water from the outside system.

The total amount of municipally supplied water must also be returned to the local water system. It is up to each utility district to determine the amount of its water effluent that will be treated and the type of treatment. The four types of outflow treatment and the percent of each pollutant that is removed appeared earlier in Figure 23.

SECTION IX

THE INTERACTION OF THE WATER SYSTEM WITH THE REMAINDER OF THE MODEL

The following description illustrates some of the features of the water component and the interaction between it and the rest of the model.

Figure 25 shows the relationships between the water component and the three sectors of the model. In the economic sector, the quantity and quality of water in the local system affects some industrial users, land values (indirectly through the neighborhood index), major recreation facilities (and the consumption they generate).

The Social Sector is affected by the water quality and quantity through the health of the local population and the environmental index (which influences the outcome of migration). Government operation interacts with the water component through the fire protection process (which is dependent upon adequate water supply), the water quality agency (the local public body concerned with water quality), and the municipal water department which in turn supplies businesses and residences.

Actually, there may not be a Water Quality Agency in the local system, or there may be several that exist for different political jurisdictions. The game part of the Water Model allows much flexibility in the way this particular function is handled. Figure 26 shows some of the interactions of the Water Quality Agency with the local system, once such an agency is in existence. The agency has legal options as well as the promotion of water treatment options by the public water and sewer authority at its disposal. The agency may also use its persuasive powers to line up support for its actions. The mix of policy that the agency undertakes will have effects on businesses and their treatment of or payment for effluent. The agency's policies will ultimately affect the people of the community and their standard of life in the local system. The Water Quality Agency will most likely be prompted to action through the complaints brought about by the population sector of the local community who find that sickness, lack of recreation, and other adverse effects result from water pollution. Complaints about poor water quality are also likely to arise from major water users who find their own inflow treatment costs to be increasing because of the deteriorating water quality.

Figure 25

INTERACTION BETWEEN THE WATER COMPONENT AND THE THREE SECTORS OF THE MODEL

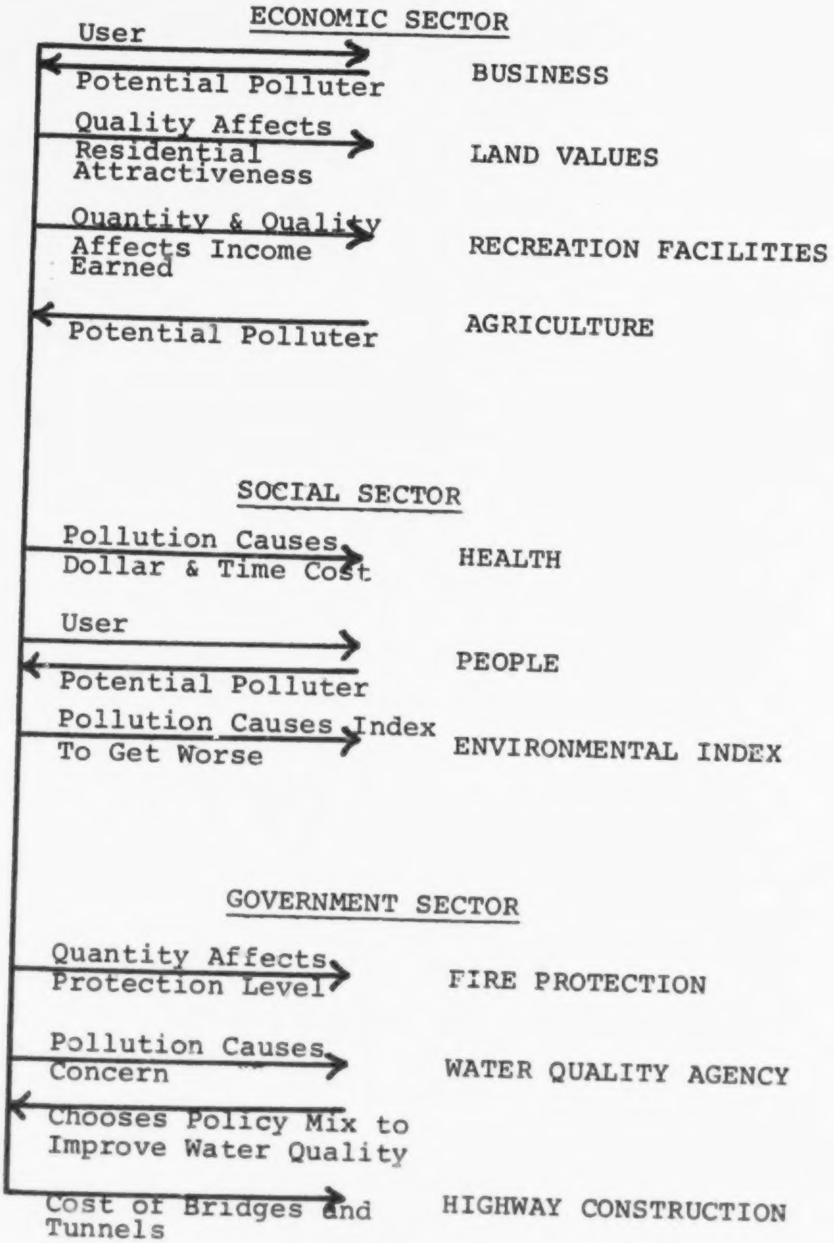
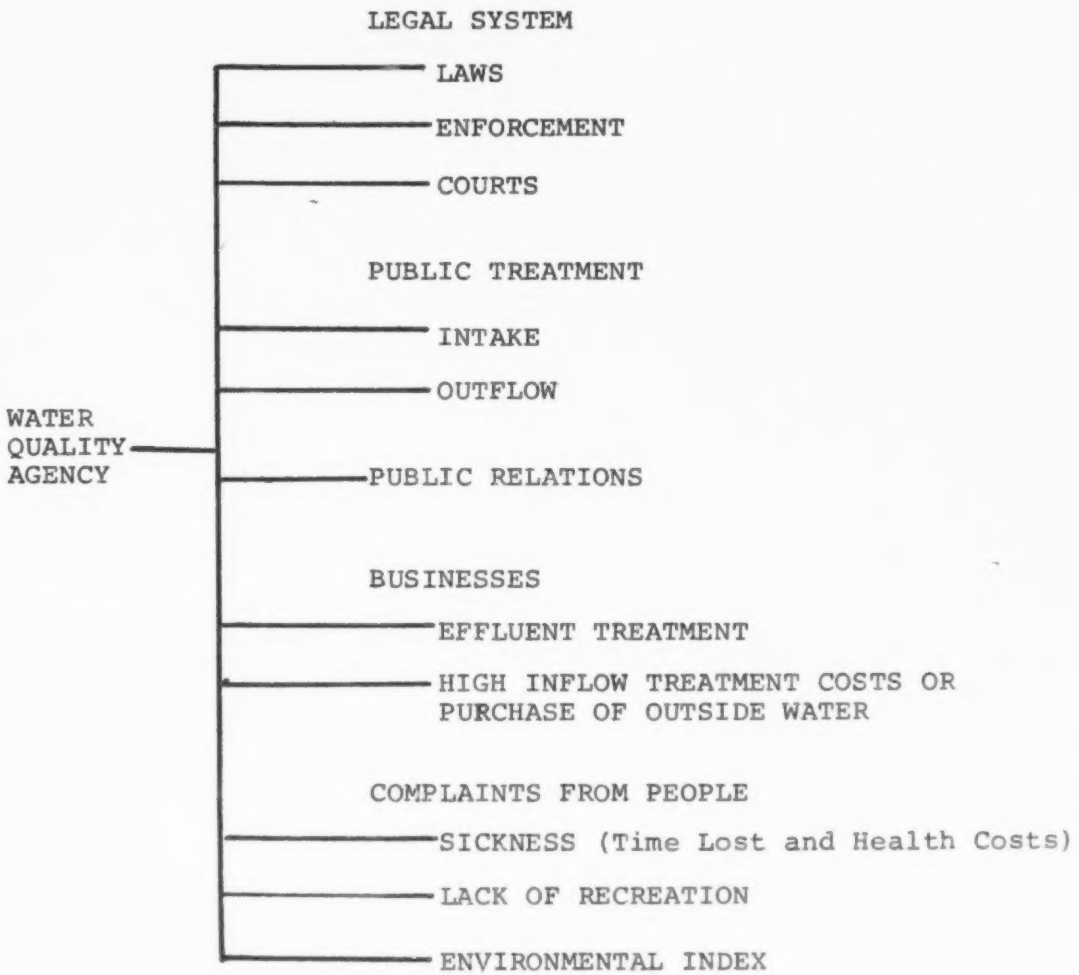

ECONOMIC SECTOR
User
Potential Polluter
BUSINESS
Quality Affects Residential Attractiveness
LAND VALUES
Quantity & Quality Affects Income Earned
RECREATION FACILITIES
Potential Polluter
AGRICULTURE
SOCIAL SECTOR
Pollution Causes Dollar & Time Cost
HEALTH
User
Potential Polluter
PEOPLE
Pollution Causes Index To Get Worse
ENVIRONMENTAL INDEX
GOVERNMENT SECTOR
Quantity Affects Protection Level
FIRE PROTECTION
Pollution Causes Concern
WATER QUALITY AGENCY
Chooses Policy Mix to Improve Water Quality
Cost of Bridges and Tunnels
HIGHWAY CONSTRUCTION

Figure 26

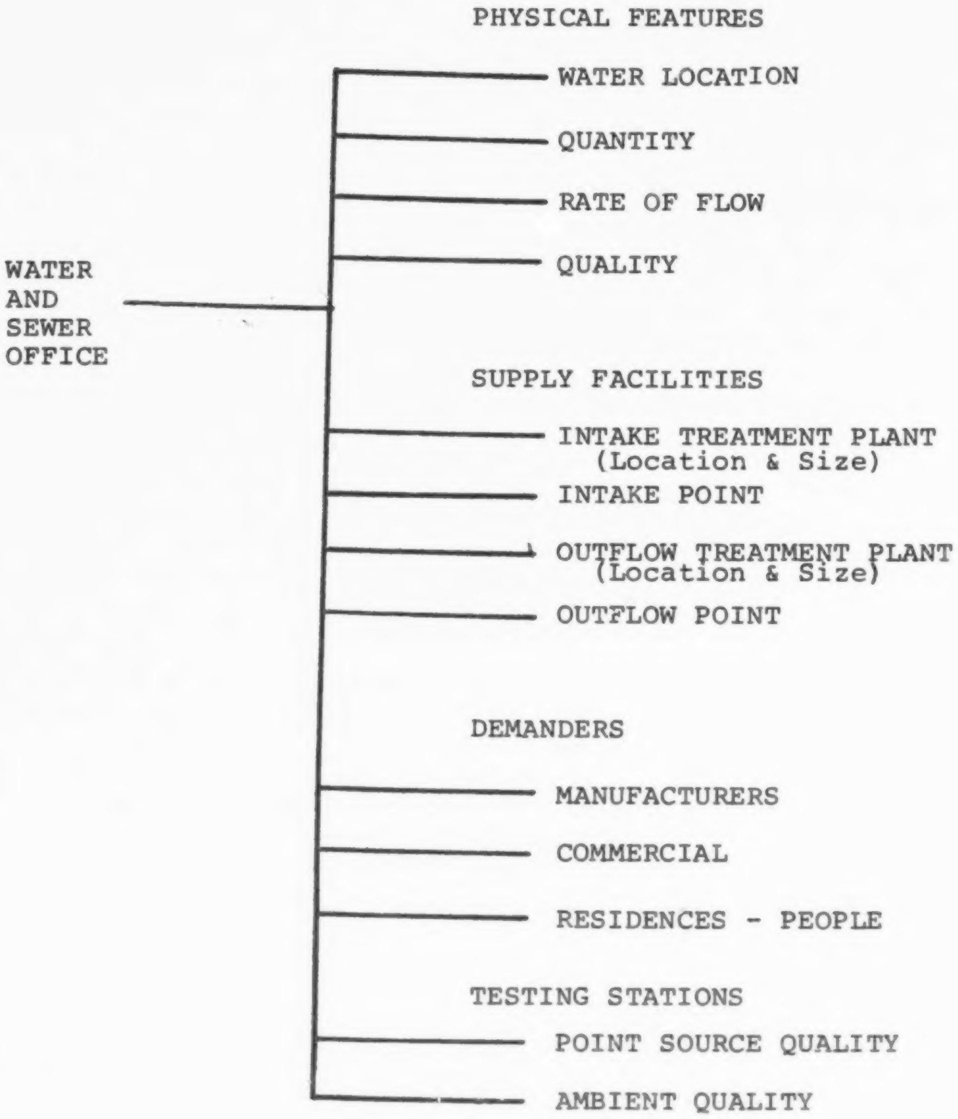
INTERACTIONS OF THE WATER QUALITY AGENCY WITH PARTS OF THE LOCAL SYSTEM


LEGAL SYSTEM
LAWS
ENFORCEMENT
COURTS
PUBLIC TREATMENT
INTAKE
OUTFLOW
WATER QUALITY AGENCY
PUBLIC RELATIONS
BUSINESSES
EFFLUENT TREATMENT
HIGH INFLOW TREATMENT COSTS OR PURCHASE OF OUTSIDE WATER
COMPLAINTS FROM PEOPLE
SICKNESS (Time Lost and Health Costs)
LACK OF RECREATION
ENVIRONMENTAL INDEX

The supply of municipal water in the local system is handled by a Water and Sewer Office. This department is concerned with the hydrological features of the local environment. As shown in Figure 27 the location of water, its amount, rate of flow, and quality is of concern to the department which has the responsibility to supply water to local demanders. To supply water, the department builds and operates intake treatment plants (at specific locations and of designated capacities) and specifies the water intake point associated with each plant. As part of the sewer responsibilities of the Water and Sewer Office, it also builds and operates water sewage outflow treatment plants (once again giving the location, treatment level, and capacity) and specifies an outflow point at which the water flows back into the local water system. The water supply authority sets a price on water for the various local demanders of water -- manufacturers, commercial activities, and residents.

Figure 27

CONCERNS OF THE WATER AND SEWER OFFICE


WATER AND SEWER OFFICE
PHYSICAL FEATURES
WATER LOCATION
QUANTITY
RATE OF FLOW
QUALITY
SUPPLY FACILITIES
INTAKE TREATMENT PLANT (Location & Size)
INTAKE POINT
OUTFLOW TREATMENT PLANT (Location & Size)
OUTFLOW POINT
DEMANDERS
MANUFACTURERS
COMMERCIAL
RESIDENCES - PEOPLE
TESTING STATIONS
POINT SOURCE QUALITY
AMBIENT QUALITY

Operating Programs

Regardless of what format is used to generate the decision inputs, the model executes the same major operating programs:

1. Migration-Housing
2. Water Quality Calculations and Effects
3. Depreciation
4. Employment
5. Transportation
6. School Allocation
7. Time Allocation
8. Commercial
9. Bookkeeping

Migration-Housing

The basic population grouping in the model is the population unit (Pl). A Pl is designated as being a member of a socio-economic class. The one thing the three classes have in common is that 500 people comprise a Pl. Pl's move into, within, and out of the local system in response to available employment opportunities, housing quantity and quality, and a number of other factors.

This computer routine calculates dissatisfaction (environmental and personal); develops a pool of movers comprised of the population displaced by housing demolition, a percent of the most dissatisfied, a percent of the total population (random movers), natural population growth, and the in-migrants; and moves the members of this pool into housing that has adequate capacity and quality. A certain percentage of each income class that are either unemployed or underemployed outmigrate from the local system. Other movers who cannot find adequate local housing also become outmigrants.

Water quality affects migration through the environmental dissatisfaction (housing near polluted water becomes less attractive) and through the personal dissatisfaction (bad health resulting from nearby polluted water increases the probability of moving).

Water Quality Calculation and Effects

The water quality on each parcel of land that contains water is calculated by combining the pollution flowing into the parcel from up to three upstream sources (water from adjacent parcels) with the quantity of water on the parcel. This mixing process generates a water quality index for water on that parcel for all users on that parcel (industries, municipal water systems, and major recreation areas). That portion of the water which is not withdrawn has a certain amount of pollution disappear based upon the rate of flow of the water. All water returned to the water system on that parcel (industrial waste, municipal outflow, and farm run-off) is combined with the water not withdrawn, and a calculation of the total amount of pollution sent to the next parcel downstream.

This process is performed for each parcel of land that contains a moving body of water. The operation of industries, municipal water systems, farms, and dams affect the water quality along different stretches of a river. The water quality then affects next year's migration and this year's depreciation and commercial activity (via major recreation areas) as indicated in the following sections.

Depreciation

Buildings and roads depreciate in value and utility each year as a function of the passage of time (obsolescence), the amount of use they receive (wear and tear), and the quality of local municipal services (especially police and fire protection). Local decision makers may choose to maintain a constant value for their developments by expending the required amounts of money for maintenance. This routine depreciates all developments and calculates maintenance expenditures.

Three additional water-related factors can also contribute to the rate of annual depreciation of developments. First, industries that draw water directly from nearby water supplies have an additional depreciation that is in proportion to the water quality rating of the water they use. Second, for utility districts that have insufficient supplies of water, there is an additional depreciation that reflects above average fire damage duetto inadequate water for fire fighting purposes. Third, developments may experience increased depreciation as a result of flood damage. This damage is related to the severity of the flood (input by the director), the type of building, its location in the flood plain, and the flood control priority of dams for the river basin (if there are any).

Employment

All P1's in the local system compete with one another for jobs in the local labor market. Likewise, all employers compete to hire workers with the highest education levels. There are two types of employment - full-time and part-time.

The full-time employment routine assigns population units (high income first and best educated first) to full time jobs based on the assumption that workers will attempt to maximize their net salary (salary received minus transportation costs using last year's transportation cost figures). Pl's will take jobs in the next lower class if none are available in their class. The part-time employment routine assigns part-time workers (80 time units in part-time work equals one full-time job) to part-time jobs on the basis of best education first. The number of time units allocated to part-time jobs is set for each group of Pl's on a parcel by the social decision-makers. If time is allocated for part-time work, but not enough part-time jobs exist, the dissatisfaction of the Pl's is increased.

If plants that are causing water pollution are shut down or forced to curtail output, then the reduction in the required labor force will have its repercussions throughout the system. The employment routine treats the former employees of the shut down plant as unemployed at the start of the routine and assigns them to other jobs if extra jobs are available in the local system.

Transportation

Pl's that are employed are assigned to a mode of travel and to a specific route by this computer routine. Taking the origins (homes as determined in migration) and the destinations (jobs as determined in employment) this allocator assigns workers to transportation mode and routes in an effort to minimize total transportation costs (dollar costs plus the dollar value of time spent) subject to the constraints imposed by public transit capacity, road congestion, and transportation boycotts.

Each employer may offer a unique salary; Pl's from a single parcel may be employed at several different locations, and three transportation modes (auto, bus, and rapid rail) may be considered. Government decision-makers may affect the transportation access (and thereby indirectly affect employment choices) by choosing where to build roads of different capacities, where to run bus lines, what fare to charge, and where to build and operate rapid rail service.

School Allocation

Each Pl contains a number of school age children who attend public schools, if the public schools are available and meet quality criteria that differ by income class. This routine assigns students by class (low class first) to public schools or private schools based upon school quality criteria (quality of plant and equipment, quality of teachers, and the student-teacher ratio) and capacity of the school serving their district. Population units who send their children to private schools as a result of local public school deficiencies must bear the cost of such private education.

Another school allocation routine assigns adults from Pl's to public adult education programs in proportion to the amount of leisure time allocated by Pl's to such programs. The local education authority provides public adult education programs by hiring teachers and using existing educational facilities. If Pl's are not able to spend as much in adult public education programs as they wanted, then their personal dissatisfaction increases.

Time Allocation

For each Pl grouping, time spent in transportation is deducted from a total of 100 units; then time spent in part-time employment is deducted; public adult education time is deducted; private adult education costs are determined and the time is deducted; voter registration is changed as a result of the time spent in politics and the time is deducted; and time is deducted for time spent in recreation, and consumption of PG and PS is increased above the normal amount. The remaining time is labeled "involuntary" time, which contributes to the level of dissatisfaction calculated for the following year.

Commercial

Each Pl grouping must purchase units of personal goods and units of personal services each year. Establishments that sell personal goods and personal services must sell exclusively to local system demanders. These establishments compete with one another through locational advantages and by prices for a unit of goods or services sold. In the commercial routine, the purchases (normal and recreation-related) of the population groups on a parcel and residential maintenance expenditures are allocated to personal goods and personal services establishments using the criteria that establishments have a limited capacity and that shoppers attempt to minimize total costs (sale price plus transportation charges).

In a similar fashion, purchasers of business goods and business services must buy annually from BG and BS establishments. These establishments compete with one another to supply the local demand. In the commercial routine, the purchasesof businesses (including personal goods and personal services establishments) for normal operation and for maintenance are allocated to business goods and business services establishments based upon the same criteria as above (an infinite-capacity outside supplier sells goods and services at prices in excess of normal local prices).

The amount of purchases from local personal goods and services establishments is affected by the normal amount of business generated by Major Recreation Areas and the present quality rating of the water bodies serving those recreation areas. Thus, consumption at local stores will rise somewhat with good water quality and fall with poor water quality. This consumption is assumed to be made by tourists from outside the local system.

Bookkeeping

This routine makes all the final calculations of incomes and expenditures and of indicators for use in the detailed computer output to the economic activities and teams, the social decision-makers, the government departments, and the summary statistics.

Interrelated Activities (Subsystems)

The basic design assumption of the model is that if the major activities that take place within a regional area are represented and related to one another, then the actual demands for water quantity and quality will result from the operation of these activities. Furthermore, the realistic way in which water resource decisions and their impacts affect the urban system can only be represented in a holistic model that incorporates public and private decision-making.

The major decision-making actors are business (the economic sector), the local population (the social sector) and public policy makers (the government sector). They interrelate with one another in a physical and institutional environment that takes into consideration spatial relationships, ties to a larger outside system, and allocates goods, services, labor, incomes, etc. by a number of market operations.

The major markets are:

1. Interrelationships with the Outside System
2. Migration and Housing
3. Employment and Transportation
4. Commercial and Transportation
5. Time Allocation
6. Public Goods and Services
7. Allocation of Financial Resources
8. Demand for and Supply of Water

The four basic building blocks of the model are business types, population units, government functions, and parcels of land. All of these factors are dealt with in a micro manner. That is, an individual population unit (representing a given number of people with loaded or derived characteristics) finds housing at a specific location, is employed by a specific employer (if in fact it is employed), shops at designated locations, etc..

Basic Building Blocks

Much of the design effort associated with the development of the RIVER BASIN MODEL was spent developing general and usable concepts of land parcels, business activities, population units and government functions. A general concept is required so that any area in the continental United States can be represented. The concepts must be usable in the sense that the users of the model are able to understand the basic system relationships of the model and the statistical output generated by the computer within a relatively short period of time.

Parcels of Land

The geographical area represented by the model will be comprised of land parcels. A parcel of land has the following characteristics:

1. A place from which distance to other parcels is measured.
2. A size (number of acres or square miles), a shape (square) and a unique identification number (pair of coordinates).
3. A number of constituent percents of land.
4. A single owner of the privately owned portion of the parcel.
5. A single zoning classification.
6. A single private land use.

All geographical areas (such as political jurisdictions, special districts, river basins, flood plains, etc.) are defined in terms of full parcels of land.

An important characteristic of the sum of all the parcels, which define the map boundaries, is that they define the geographical limits of the local system. All activities and decision-makers that are outside of the regional boundaries comprise the outside system. There may be some activities (Federal installations and state institutions) and some decision-makers (at the Federal and state level) that are physically within the boundaries of the region. These activities and their employment impacts are part of the local system, but their policy is made as part of the outside system (exogenous).

Business Activity

The RIVER BASIN MODEL contains business activity within four categories: manufacturing, commercial, residential, and farms. Within each of these categories there may be many specific business types. For example, eleven types of manufacturing may be represented, five types of commercial, three types of residences and five types of farms. Business activities must be located on parcels of land. The production function for each manufacturing and commercial business is dependent upon the quantity and quality of plant and equipment, and the amount of labor hired.

SECTION X

APPENDICES

	Page
APPENDIX A - EXAMPLE OF THE CALCULATION OF THE WATER QUALITY ON A PARCEL	84
APPENDIX B - PROGRAMS OF THE COMPUTER PROGRAM	93
APPENDIX C - SIMPLIFICATIONS IN THE MODEL	96
APPENDIX D - AGGREGATION IMPLICATIONS	101
APPENDIX E - SELECTED BIBLIOGRAPHY	103
APPENDIX F - UNITS OF MEASURE	106

FIGURES

Figure		Page
A-1	Visual Representation of Water Activity on a Selected Parcel	85
A-2	Definition of the Nine Comprehensive Water Quality Levels	87
A-3	Water Withdrawn, Not Withdrawn, and Added To a Parcel	88
A-4	Elimination of Three Pollutants Due to Time in the Water	90
B-1	Alphabetical List of the Programs That Comprise the River Basin Model	94
C-1	Percent of Original Pollution Remaining As a Function of the Number of Parcels Downstream and the Rate of Flow of the River (Time)	99

Preceding page blank

APPENDIX A

EXAMPLE OF THE CALCULATION OF THE WATER QUALITY ON A PARCEL

The workings of the water system can be illustrated by an example of how water quality in a river is treated on a single parcel of land for a typical working day in the year. Assume parcel A has been loaded to receive the flow of water from B and C, and to empty into D (Figure A-1).

The loaded values for A are the MGD (millions of gallons per day) on the parcel (a measure of the maximum volume of water on the parcel that may be tapped by users) and the rate of flow of the water (in parcels per day). The percent of the area of the parcel that is consumed by the river is also part of the load data, but it is not systemically related to the performance of the river.

The water volumes that flow into A from B and C do not have to equal the volume that flows from A to D. It is assumed that feeder streams and small rivers not explicitly represented by the model may contribute to the increased volume of water on parcel A.

1. Calculation of the Initial Water Quality on a Parcel

The values of water inflowing to parcel A from parcels B and C, in conjunction with the concentrations of each pollutant type, are important in determining the water quality on A. The product of the pollutant concentration and the volume of the water yield the pollutants in each of the seven categories that flow into A. These are mixed together and related to the water volume on A to determine pollution concentrations, which in turn yield the water quality level on parcel A.

Assume the following numbers relate to parcel A

$\text{MGD}_A = 100$

$\text{Rate of Flow}_A = 6$ PARCELS/DAY

and the following pollutants are contributed by parcels B and C

$\text{BOD}_B = 500$ LBS/DAY

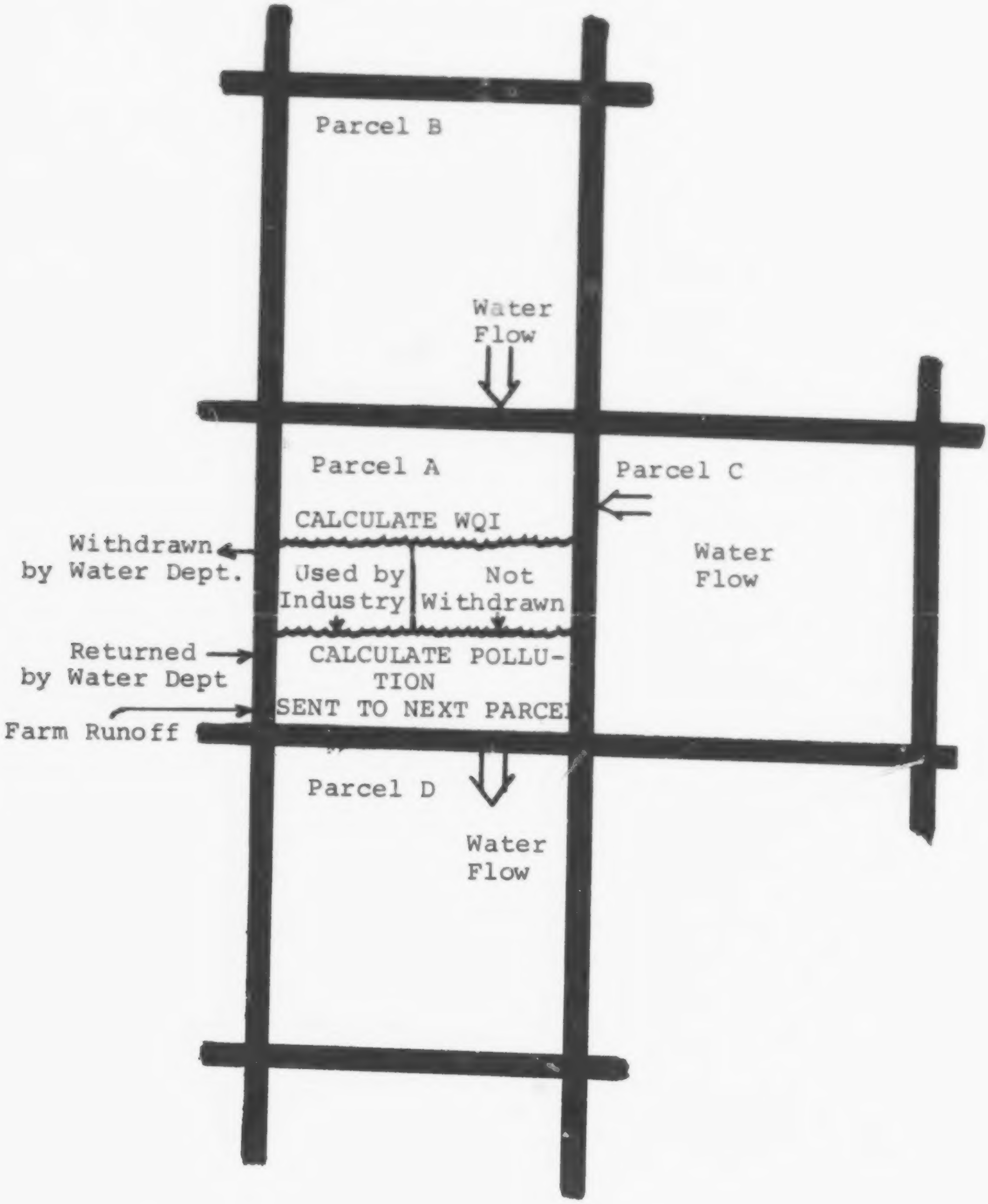
$\text{BOD}_C = 2400$ LBS/DAY

$\text{Chlorides}_B = 150$ LBS/DAY

$\text{Coliform}_C = 65$ PARTS/DAY

Figure A-1

VISUAL REPRESENTATION OF WATER ACTIVITY ON A SELECTED PARCEL


Parcel B
Water Flow
Parcel A
Parcel C
CALCULATE WQI
Withdrawn by Water Dept.
Used by Industry
Not Withdrawn
Water Flow
Returned by Water Dept
CALCULATE POLLUTION
SENT TO NEXT PARCEL
Farm Runoff
Parcel D
Water Flow

If these were the only pollutants inflowing to A, then the water quality index for parcel A would be calculated as a function of these three pollutant categories.

The water quality level based upon each pollutant category is calculated separately:

1) Calculation of quality level based upon BOD:

$$\frac{BOD_B + BOD_C}{MGD_A} = \frac{500 + 2400}{100} = 29 \text{ LBS/MG}$$

This concentration of BOD gives an initial water quality level of 3. (See Figure A-2)

2) Calculation of quality level based upon chlorides:

$$\frac{Chlorides_B}{MGD_A} = \frac{150}{100} = 1.5 \text{ LBS/MG}$$ (yields a water quality level of 1)

3) Calculation of quality level based upon coliforms:

$$\frac{Coliforms_C}{MGD_A} = \frac{65}{100} = .65 \text{ parts per MG}$$ (yields a water quality level of 1)

Therefore, the actual water quality index for parcel A is the highest of the above three calculations, or 3. This means that the water users who use the water on parcel A collectively have access to 100 MGD of water with a quality level of 3. It is this quality level that is used to derive the pollution index for parcel A. This is also the quality level that determines the cost borne by water users who use surface water from that parcel.

2. The Use of Water on the Parcel

Conceptually the water on a parcel can be looked at as shown in Figure A-3.

All of the water that is withdrawn by industries that are surface water users is returned to the system before the water leaves the parcel. The Water Department may withdraw water from the parcel and dump it back onto the same parcel, or it may dump it on a downstream parcel. Or the Water Department could dump water onto parcel A that it withdrew from an upstream parcel.

The types of activities that draw water from a parcel are:

Figure A-2

Definition of the Nine Comprehensive Water Quality Levels

Pollutant Types	Water Quality Levels								
	1	2	3	4	5	6	7	8	9
BOD (LBS/MG)	10	20	30	40	60	100	150	300	> 300
Chlorides (LBS/MG)	5	10	15	20	30	40	60	80	> 80
Nutrients (LBS/MG)	25	50	100	200	400	800	1600	3200	> 3200
Coliform Bacteria (parts per MG)	2	6	12	20	40	70	120	160	> 160
Temperature	0	0	1	2	4	7	10	14	> 14
Oil & Floating Solids	0	0	0	0	0	> 0	> 0	> 0	> 0
High Level Wastes	0	0	0	0	0	0	0	> 0	> 0

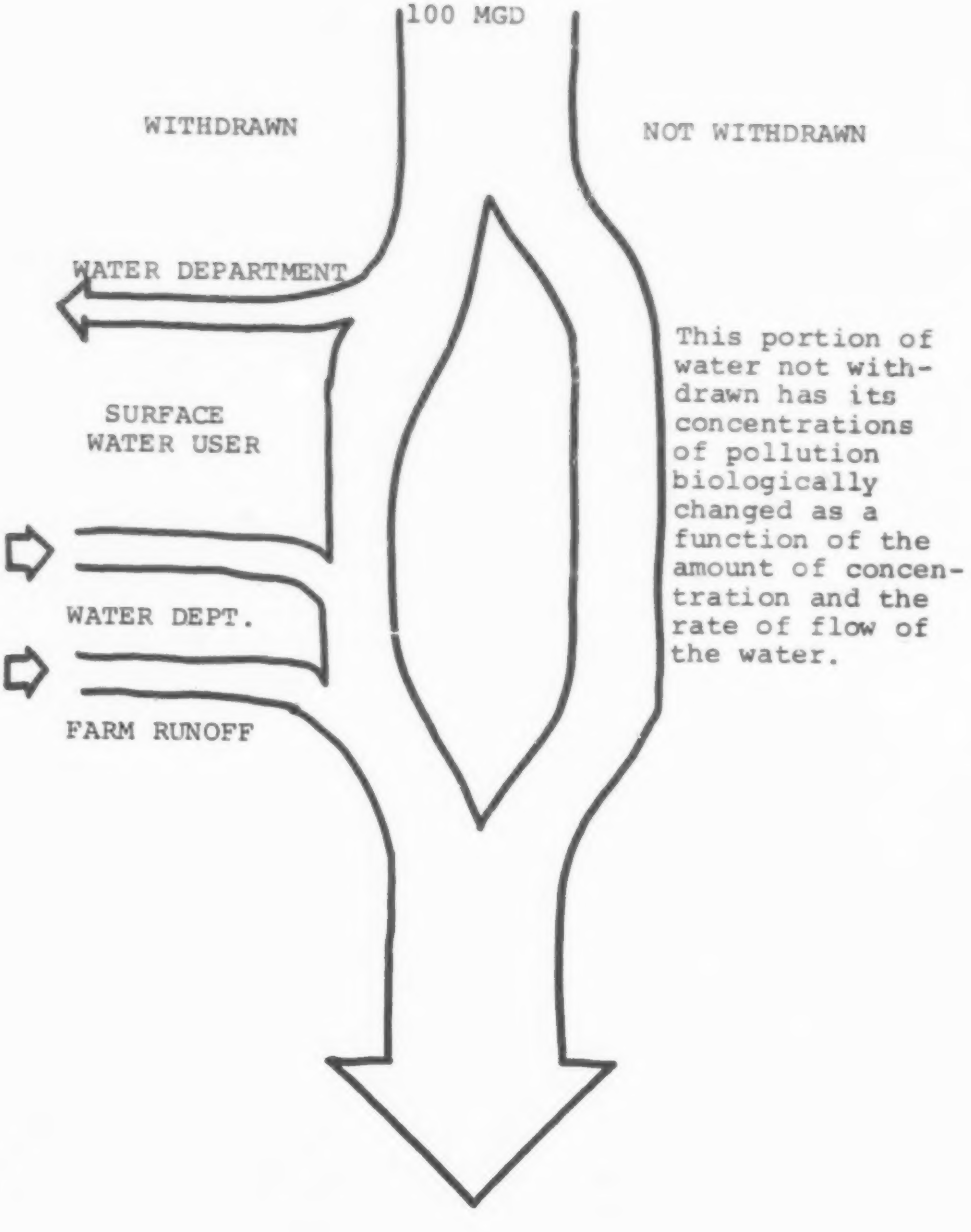
Explanation of the Table

In order to determine the water quality level or index of given amounts of water, take the concentrations of each of the seven pollutant categories and calculate the water quality level based upon each pollutant separately. For example, a BOD concentration of 25 LBS/MG would yield an index of 3, coliform bacteria of 169 parts per MG would yield an index of 9, and the presence of oil and floating solids would allow the water quality to be no better than 6. The worst (highest) water quality index that was calculated using the pollutant types separately, is assigned to the given amount of water. If the water on parcel x had the three pollutants described above, it would be assigned water quality index of 9.

Looked at another way, water quality level 4 is attained when a body of water has concentrations of BOD that exceed 30 but fall below 41, coliform bacteria concentrations above 12 but below 21, etc.

Figure A-3

WATER WITHDRAWN, NOT WITHDRAWN, AND ADDED TO A PARCEL


100 MGD
WITHDRAWN
NOT WITHDRAWN
WATER DEPARTMENT
SURFACE WATER USER
WATER DEPT.
FARM RUNOFF
This portion of water not withdrawn has its concentrations of pollution biologically changed as a function of the amount of concentration and the rate of flow of the water.

Water Department (at an intake parcel)
Surface Water Users (at the plant location parcel)

The types of activities that pour water into a parcel are:

Water Department (at an outflow parcel)
Surface Water Users (at the plant location parcel)
Farms (at runoff parcels)

The intake and outflow parcels for the Water Department plants are policy decisions. Surface water users intake and outflow on the parcel on which they are located. Farm runoff flows onto parcels that are pre-specified and do not change.

3. Water Not Withdrawn

For that portion of the water on a parcel that is not withdrawn for use, a chemical process takes place which reduces the concentration of pollution in that portion of the water.

In our example, assume that ninety percent of the water was not withdrawn. Therefore, 90 MGD of the quality 3 water will go through this chemical process. The specific pollutants of this water as it entered the parcel were:

BOD = 29 LBS/MG
Chlorides = 1.5 LBS/MG
Coliform = .65 parts per MG

Figure A-4 indicates the percentage of BOD and Coliform that will remain in the unused water after it flows through the parcel. The unused water is combined with the used water as they both leave the parcel. With a Rate of Flow of 6 parcels per day, the concentrations of BOD and Coliform in the unused water after flowing through the parcel are 27 LBS/MG and .56 Parts/MG, respectively. Chlorides do not biodegrade, so the amount of chlorides is still 1.5 LBS/MG.

4. Water Withdrawn and Returned by Industry

Industrial surface water users draw water from the parcel (if it is not the poorest quality water -- level 9) and treat it so that it is usable for their purposes. As a result of their production process they add pollutants to the water they use. It is the choice of these industries or, possibly a legal requisite, to treat their outflow and thereby remove all or part of the pollution in the water they return to the water system.

Figure A-4

Elimination of Three Pollutants Due to Time in the Water

	Percent of Original Pollutant Remaining at the End of a Flow Through a Parcel		
Rate of Flow of the River (parcels per day)	BOD	Nutrients	Coliform
1	50	33	17
2 (sluggish)	75	67	58
4	89	83	79
6 (slow)	92	89	86
8	96	92	90
11 (average)	96	94	93
15	97	96	95
22 (fast)	97	97	96
30	98	98	97
44 (rapid)	99	99	98

Assume that there is a surface water user which uses 10 MGD and returns that much water with the following pollution concentration characteristics:

BOD = 100 LBS/MG
Chlorides = 50 LBS/MG
Coliform = 5 parts per MG

Since this industry uses 10 MGD its total pollution for the day is 1000 LBS of BOD, 500 LBS of Chlorides, and 50 parts of Coliform. This pollution is added to the pollution coming from other sources to calculate the pollution concentrations leaving parcel A.

5. Water Withdrawn by the Water Department

If water is withdrawn from a parcel by the Water Department it need not be returned to that parcel. Assume that no water was withdrawn from parcel A for use by the Water Department.

6. Water Returned by the Water Department

The Water Department may or may not treat the outflow from one of its plants that outflows onto parcel A. In any case, the water returned will have an accompanying concentration of some or all of the pollutants. Assume that 20 MGD of water were returned to parcel A by the Water Department and that it had the following pollutants:

BOD = 50 LBS/MG
Chlorides = 10 LBS/MG
Coliform = 15 parts per MG

This pollution is added to the pollution coming from other sources to calculate the pollution concentrations leaving parcel A.

7. Water from Agricultural Sources (Runoff from Farms)

Although agricultural activities do not withdraw water from the water system, it is possible for run-off from farms to flow into the water system. Farms create pollution in relation to the type of farms and the amount of fertilizer used. Assume that the farm run-off to parcel A was 10 MGD and it had a concentration of nutrients of 100 LBS/MG. This pollution is added to the pollution coming from other sources to calculate the pollution concentrations leaving parcel A.

8. Calculation of the Final Pollution Concentrations on a Parcel

The concentrations of each of the pollutant categories on parcel A are calculated so that they may be used to compute the water quality level on the parcel into which they flow.

The concentrations by pollutant category for parcel A are as follows:

	LBS/MG	MGD	LBS
BOD:			
Water Not Withdrawn	28	90	2520
Industrial Water	100	10	1000
Water Department Return	50	20	1000
Farm Runoff	0	10	0
Total Pounds			4520
Concentration (LBS/MG) . . . 45.20			
Chlorides:			
Water Not Withdrawn	1.5	90	135.0
Industrial Water	50.0	10	500.0
Water Department Return	10.0	20	200.0
Farm Runoff	0	10	0
Total Pounds			835.0
Concentration (LBS/MG) 8.35			
Coliform:			
Water Not Withdrawn	.59	90	53.10
Industrial Water	5	10	50.00
Water Department Return	15	20	300.00
Farms	0	10	0
Total Parts			403.10
Concentration (Parts per MG). . . 4.03			
Nutrients:			
Farms	100	10	1000
Total			1000
Concentration (LBS/MG) . . . 10.00			

APPENDIX B

PROGRAMS OF THE COMPUTER PROGRAM

The computer program for the River Basin Model is comprised of 325 sub-programs. These programs are listed in Figure B-1. Some of the programs are service routines used a number of places in a cycle of the model, while others are very specific programs that are used only once during a cycle.

The modules of the model are composed of one or more of these programs. For example, the Migration Modules uses the following 12 programs to move population units into, out of, and within the local system.

1. HSDSST - calculate and stores dissatisfaction indices for all Pl's on board.
2. GETCUT - determines what personal dissatisfaction constitutes a 20% cutoff point for each class.
3. MOUOUT - determines how many Pl's of each class on each residence working at each employment location will move out for reasons of (1) unemployment, (2) underemployment, (3) mobility, or (4) dissatisfaction.
4. UNCRWD - calculates percent occupancy of each residence and determines how many Pl's of each class on each residence must move out as a result of overcrowding.
5. DISPLC - determines how many Pl's of each class on each residence working at each employment location will move out in order to move out enough to satisfy UNCRWD's requirements.
6. INMIG - determines how many immigrants will move in and how much natural population growth there will be.
7. SETUP - determines where Pl's will move into, using PICKRS.
8. PICKRS - finds best available and acceptable housing.
9. MOVFN - does actual moving in of Pl's as determined by SETUP.
10. JANOUT - prints migration detail.
11. MIGSUM - prints migration summary.
12. KLEAR - tidies up after housing demolitions.

Figure B-1

Alphabetical List of the Programs that Comprise the RIVER BASIN MODEL

1. ACAUC
2. ACBLD
3. ACBMAIN
4. ACRID
5. ADDBUS
6. ADDCTU
7. ADDPOL
8. ALCMAIN
9. APACK
10. APPROP
11. AS
12. ASSESR
13. ASSESS
14. ASSOUT
15. ASVMP
16. ASVSET
17. AUCTN
18. AVAILL
19. AVLDSB
20. BGBSCT
21. BLANK
22. BLC
23. BLDRR
24. BNDNTY
25. BNDPAY
26. BNDPT
27. BONDS
28. BOUND
29. BOYCOT
30. BSHMAIN
31. BSRROT
32. BTMBND
33. BUILD
34. BUSDMP
35. CHGUTS
36. CHKRTN
37. CHPAR
38. CHPVT
39. CHRTRN
40. CHTRK
41. CITEAM
42. CNTRCT
43. COLAP
44. COMCON
45. COMDIG
46. CONAC
47. CONGES
48. CONIN
49. COUNTR
50. CTYLOD
51. CTYMAIN
52. DAMPR
53. DBND
54. DEMMP
55. DEPREC
56. DIST
57. DOBLDS
58. DSTLD
59. DUMIES
60. ECBOY
61. ECNSTM
62. ECSUM
63. EDIT
64. EDLEVL
65. EDORD
66. EDTMAIN
67. EMP
68. EMPLOC
69. EMPMAIN
70. EMPRT
71. EMPSUM
72. EMPTAX
73. ENDS
74. FARES
75. FBUSS
76. FETCEN
77. FISTA
78. FMDATA
79. FNDLET
80. FNDTEM
81. FNDTYP
82. FORTPRE
83. FRMLND
84. FRMMAP
85. FRMOUT
86. FSA
87. FSAAMT
88. FSMAX
89. FTCHVK
90. FXDWTR
91. GAILMN
92. GETBLK
93. GETCUT
94. GETVAL
95. GOVMNT
96. GVTSMP
97. HDSDP
98. ADEN
99. REDE
100. HISTCK
101. HISTLD
102. HISTRE
103. HLTCST
104. HRTRN
105. HSDSST
106. HSDSSW
107. HWYMAP
108. HYWAY
109. IBCOR
110. IBIN
111. IBLIN
112. IBLOCK
113. IBNPY
114. ICOTRN
115. IDEMCI
116. IDEMEC
117. IDLIN
118. MAINPGM
119. IEF
120. IFIND
121. ILFACOM
122. ILFALL10
123. ILFCLAS
124. ILFCSAS
125. ILFEXT10
126. ILFFINT
127. ILFFORT
128. ILFGEN10
129. ILFLERF
130. ILFLEXP
131. ILFLLOG
132. ILFLSCN
133. ILFPAR10
134. ILFROL10
135. ILFSERF
136. ILFSEXP
137. ILFSLOG
138. ILFSSCN
139. ILFTRBK
140. ILFUNF10
141. ERMESG
142. IODF
143. CHARS
144. INRTNS
145. TNAME
146. NAMLU
147. SOCIAL
148. INMIG
149. INROAD
150. INRTN3
151. IOCF
152. IRLIN
153. JANOUT
154. JANOUW
155. JURWRD
156. KLEAR
157. LANDO
158. LINT
159. LITR
160. LNDHWY
161. LNDMNS
162. LNDPAR
163. LNDPRK
164. LNDSCH
165. LNDTRM
166. LNDUNH
167. LNDUTS
168. LOADMS
169. LOADSC
170. LOANS
171. VECBLK
172. NLNCDS
173. CNTRL
174. VECTOR
175. LONSOT
176. LOSTA
177. LUTS
178. MAJREC
179. MAPMAIN
180. MIGMAIN
181. MIGRAT
182. MIGSUM
183. MKVMP
184. MOVIN
185. MOVOUT
186. MSMAP
187. MSQUAL
188. MSREQT
189. MUMAP
190. MUNPLT
191. MUNPTS
192. MUSER
193. NAMET
194. NCHPVT
195. NCHPVT
196. NEWBND
197. NEWCOD
198. NEWCON
199. NEWJOB
200. NSPACK
201. NUMDT
202. NUMEDT
203. ODDS
204. OPCM

205. OPCMAIN
206. OUTPCU
207. PARCRD
208. PBCMST
209. PBDEBT
210. PEOPLE
211. PGMP
212. PGMPS
213. POPCNT
214. PRCHED
215. PRCSET
216. PRINTY
217. PRIVAT
218. PRKLOC
219. PRYMAIN
220. PRYMAN
221. PRYOU
222. PU
223. PUBMAIN
224. PUNC
225. PUTNUM
226. PWS
227. PZ
228. PZMAP
229. RAIL
230. RAND
231. RANGUS
232. RCASH
233. RDMTLV
234. RDWEAR
235. RECCHK
236. REDE
237. REDIST
238. RENTS
239. RETER
240. RIVWAT
241. RLSBLK
242. ROUTES
243. RTBLD
244. RTEMP
245. SALTAX
246. SAMPL
247. SCECMP
248. SCHOUT
249. SCHPVT
250. SCMAP
251. SCRNCH
252. SDMMP
253. SETALL
254. SETCAP
255. SETCOM
256. SETDAM
257. SETEMP
258. SETLAM
259. SETRSZ
260. SETSTF
261. SETUP
262. SINDEX
263. ECBOY
264. SOCNAM
265. SOCSUM
266. SORTEM
267. SPLIT
268. SPPTEM
269. START
270. STPTRN
271. TALOC
272. TAXES
273. TAXEZ
274. TAXSUM
275. TERMS
276. TMALC
277. TMCSH
278. TMVAL
279. TOPRES
280. TPRMP
281. TRCMAIN
282. TREAT
283. TRKMAP
284. TRMMAIN
285. TRNCMP
286. TRTRC
287. TRTST
288. TRTYP
289. TSBYC
290. TSCAN
291. TYMALC
292. UNCRWD
293. UNPRTX
294. UNUSE
295. UTCMP
296. UTMAP
297. UTS
298. VALU
299. VALUE
300. VECDEF
301. VECDFL
302. VECDMP
303. VOTES
304. VSTALL
305. WATOUT
306. WBUSS
307. WHD1
308. WLFSUB
309. WPRYOU
310. WRBLD
311. WRCST
312. WRITM
313. WRPRC
314. WRRES
315. WRTBAL
316. WRYMAIN
317. WRYOU
318. WTRHWY
319. WTRINP
320. WTRMAP
321. WTRPRC
322. WTRQUL
323. ZEREN
324. ZERO
325. ZRLL

APPENDIX C

SIMPLIFICATIONS IN THE MODEL

In order to make the River Basin Model practically usable, and still not require that the players have previous water management experience (or business or government experience, either), it was necessary to simplify the complexity that actually exists in the way water is used; the way pollutants are generated, treated, and degraded in the water system; the way water prices are set, and the way businesses and government departments operate.

This means that a number of factors are omitted or are lost in the aggregation, linear relationships are employed in cases where in reality a more complex functional relationship is involved, and attention is paid to making relationships understandable to the model users. This last model-building guideline is difficult to achieve because of the large number of factors involved and related to one another in the model.

To illustrate some of the model-building trade-offs that constantly cropped up in the RIVER BASIN MODEL, the case of the biodegradation of pollutants will be discussed.

Biodegradation of Pollutants

Because of a lot of other considerations, the number of pollutants that the model would deal with was reduced to seven: BOD, chlorides, nutrients, coliform, temperature deviations, oil and floating solids, and high level wastes.

Several of these pollutants tend not to disappear or be reduced in magnitude as a result of the time they are in the water (for example, chlorides, oil and floating solids, and high level wastes).

Initially (Spring of 1971) it was decided that there would be some dimunition of chlorides over time (due to settling to the bottom of the water) and no dimunition in the other two persistent pollutants. By late 1971, a complete reversal had been made. As the result of a meeting with EPA personnel, it was decided not to have chlorides biodegrade at all. The other two pollutants, oil and floating solids and high level wastes, were made to disappear after being in the water for five parcels downstream from where they were dumped. There is no way to rationalize the disappearance of these two types of pollutants in such a short span (12 1/2 miles downstream). The change was made because several runs of the model with the assumptions of no disappearance and with disappearance after 10 parcels gave results and water quality levels that we felt were too much of a penalty for water users many parcels downstream. Therefore, the design staff made the value judgment that for playability purposes these two pollutants should disappear after being in the water for five parcels downstream from where they are dumped. Any model user who does not agree with this value judgment (either on scientific or playability grounds) will find that a systems analyst can change that parameter with very little difficulty.

The temperature measurement is deviations from the normal temperature (assumed to be 75 degrees F). Since heat dissipates rather quickly, it was assumed that the temperature would drop a certain number of degrees each parcel. This is reasonable especially since a parcel is 2 1/2 miles in length.

Coliform bacteria actually has a period of multiplication (about its first 1/2 day in the water) before dying off. Rather than represent this, we made the assumption that the coliform generated by residences and industries remained in the internal sewers for the first 12 hours before being released into the surface water system. In this way, it was necessary to represent only the decay portion of the coliform bacteria life cycle.

The same type of equation is used to represent the decay of coliform bacteria, BOD, and nutrients. Only the coefficients of the equation are changed from one type of pollutant to another. The basic equation is:

$$A_t + A_{t-1} (1- \frac{1}{C*ROF}$$

where

A = The amount of the pollutant (LBS or PARTS)
C = A coefficient that is different for each pollutant type
ROF = Rate of flow of the river (a measure of time)

Thus, the amount of each of these pollutants that remains in the water at any point downstream from a discharge point is dependent upon a coefficient value and the time that the pollutant has been in the water.

Figure C-1 shows the shape of the curve for this equation for several values of ROF and with C=2. These curves are easy to understand and easy for players to deal with.

The actual decay equation for BOD is of the form

$BOD_t = BOD_{t-1} [e^{-kt}]$ a)

---

a) Source: Robert Dorfman and Henry D. Jacoby, "A Model of Public Decisions Illustrated by a Water Pollution Policy Problem, "The Analysis and Evaluation of Public Expenditures: The PPBS System. Government Printing Office, Washington, 1969. (p. 269) where

k is a constant
t = time

It would give shapes like those shown as dotted curves in Figure C-1. There is not enough difference between the shapes of these curves (they are not drawn to be as similar to one another as possible) to make an appreciable difference in the effects generated by the model and the playability of the RIVER BASIN MODEL.

Simplifications in the Water Component

Several additional water relationships could have been included in the model (some were designed but not implemented because it was thought that they would add more complexity than benefit to the use of the model):

1. Synergism among pollutants as they biodegrade. For example, the temperature of the water affects the rate at which nutrients biodegrade. Likewise, nutrients and BOD interact when in the water together.

2. Water absorption by water users. It was assumed for play ability purposes that all the water withdrawn by industries is returned to the system whereas in the real world CR would return only 95%, MP - 99%, TE - 92%, PA - 94%, etc. On the average, industries absorb about 6% of the water.

3. Seasonal differences in water use. The water quality measured in the model is the average quality for a typical work day. No attempt was made to show the variations that might take place within a year.

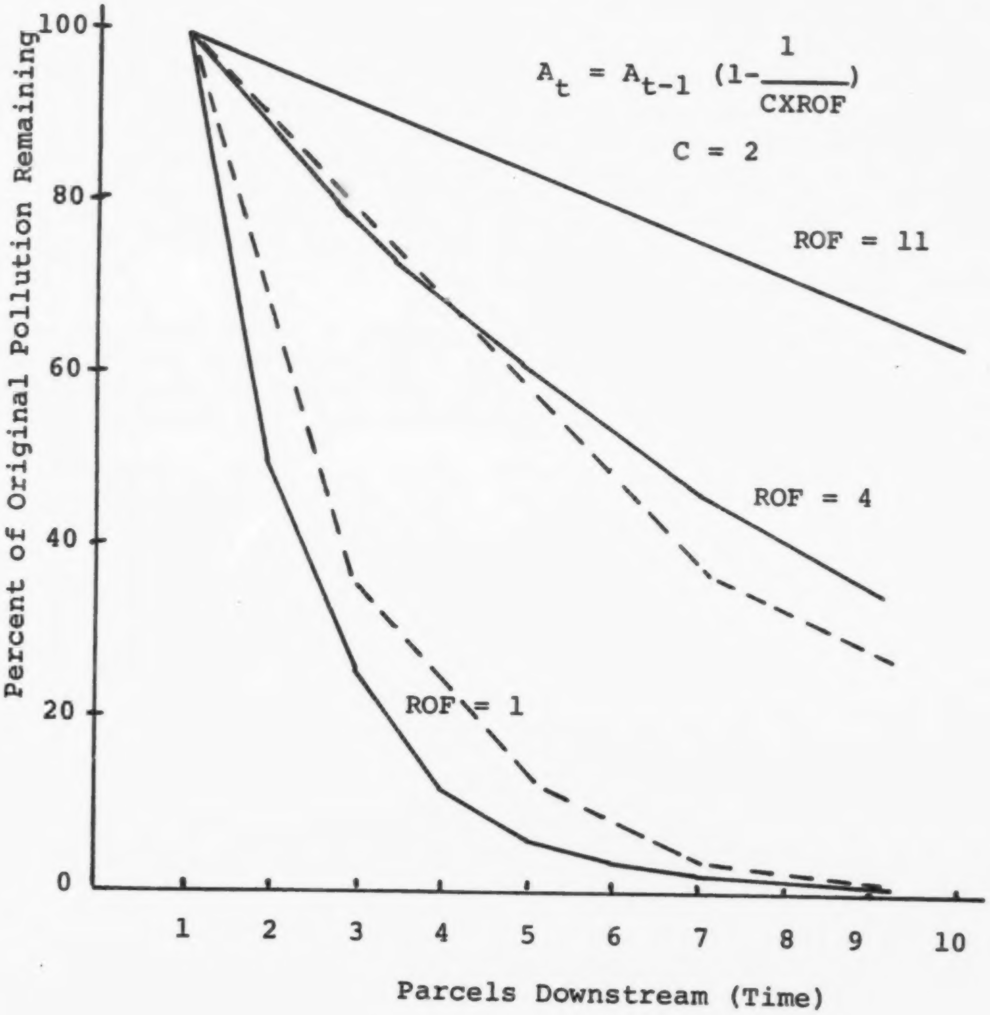
4. The effects of urbanization. The urban run-off generated by various densities of development are not measured in the model.

5. Power plants. The tremendous heat generated by nuclear power plants is not represented in the model because the Utility Department is not provided with options for the types of utility plants it may construct and operate.

It should be kept in mind, however, that all of these items could be added to the model with very little trouble.

Figure C-1

Percent of Original Pollution Remaining as a Function of the Number of Parcels Downstream and the Rate of Flow of the River (Time).



Determination of Quality Levels

Estimates of what concentrations of pollutants in the model caused a level 9 water quality rating were derived from numbers contained in a paper entitled "A Water Quality Index --Do We Dare?" by Robert M. Brown, et al. This groundbreaking paper was prepared for the National Symposium on Data and Instrumentation for Water Quality Management held in July 1970 at the University of Wisconsin. In it the authors used opinion research to determine the inclusion and weighting of factors to be used in a comprehensive water quality index.

The concentrations that would cause the worst quality stream in their terms were used to define the quality level in the RIVER BASIN MODEL terms. It may be that this was too restrictive a definition, especially since the model assumes the quality level 9 water is unusable. Persons who disagree with this formulation can make a minor design change to alter the quality 9 level definition or to make quality 9 level water usable at some treatment cost.

There are some disadvantages to having a water quality level that cannot be used even at very high treatment costs as the model assumes. But conceptually, the price of outside system water can be viewed as the treatment cost for level 9 water.

APPENDIX D

AGGREGATION IMPLICATIONS

The aggregation assumptions in the River Basin Model allow the model to deal with something as complex as a regional system in terms that are manageable. In the social sector, the assumption of 500 people to a population unit (P1) means that the Cuyahoga River Basin area has about 5000 population units. This large a number of P1's causes the running time of some of the computer programs to be relatively large. If it were assumed that each P1 were 50 people, the running time might increase by as much as a factor of ten (assuming that the core storage could handle 50,000 P1's).

An example of aggregation in the Government Sector is the school facility. The smallest school facility has a design capacity of 20,000 students (including all grades, 1 through 12) and 840 teachers. If the model were being used for school planning purposes, this would be unacceptable. The importance of the school system at the general level of detail contained in the RIVER BASIN MODEL is to provide the major short run impacts of the educational facilities on the local system: high operating costs, quality considerations for residential selection, land use, employment impact, and share of the local budget. When the model is being used by water resource planners or others primarily concerned with water quality in the represented river basin, the level of aggregation employed with regard to the School Department is probably acceptable.

In the Economic Sector, the eleven types of manufacturing are aggregated economic business that roughly represent average two-digit SIC (Standard Industrial Classification) groupings of industry with regard to land consumption per employee and employee mix by income class. The pollution characteristics of these industries are also averages (nationwide, at that). This averaging within industry groups overlooks the fact that there is more variation within a two-digit SIC industry with regard to pollution generated than there is across average SIC groupings. For example, within the industry called CR (Chemicals and Rubber) in the model there are such real life activities as manufacturers of coal tar products, plastics, synthetic rubber, soaps, pharmaceutical preparations, paints, fertilizers, and explosives.

Example: Treatment Costs

Note that the cost of building a treatment plant varies per MGD for the Water Department but not for the industries. This means that economies of scale are represented in the public sector but not in the private sector. The reason for this is that a Waste Treatment Plant in the public sector of the model closely approximates in size the level of an actual real world facility. That is, treatment plants of 3 MGD or 13 MGD capacity are not of unreasonable size.

Due to aggregations in the model, however, the common factor to all of the level one industries in the economic sector is that they employ 10,000 workers. Thus a level one industry must be looked at as a conglomerate of smaller real life businesses. It was decided, therefore, not to represent economies of scale in the private sector because the increase in operation from a level one to a level two in the model must be viewed as the growth of a lot of small scale industries and/or the addition of a group of industries, each employing less than 10,000 workers, in the real world. The same reasoning explains why surface water users that have widely different water needs still pay the same cost per MG of treatment and treatment plant facilities.

Another assumption in the treatment cost for industries is that it costs all of them the same amount of money to improve the water quality of an MG of water. The only treatment costs that are different is the cost needed to treat water of the best quality and make it suitable for their particular production process.

APPENDIX E

SELECTED BIBLIOGRAPHY

The following bibliography is not meant to be exhaustive. It is a selection of the research material that we found most helpful in formulating the structure and some of the numbers in the model. A good part of our insights into the regional water management decision process was derived from conversations with persons from the Environmental Protection Agency and other environmental groups.

Man and His Environment - America's Water Crisis.
AFL-CIO Report submitted to US Senate, 91st Congress, 1st Session, Commission on Interior and Insular Affairs - Apr.16, 1969.

A Framework for Action - The comprehensive report of the Cleveland/Seven County Transportation/Land Use Study Project No. 003414. 1st Edition: May 69. Second Edition: Jun. 69.

A Water Quality Index - Do We Dare?
Robert M. Brown, Nina I. McClelland, Rolf A. Deininger and Ronald G. Tozer
In Proceedings of the National Symposium on Data and Instrumentation for Water Quality Management
University of Wisconsin, Water Resources Center
Madison, July 21-23, 1970.

"Projections of Water Requirements and The Economics of Water Policy."
Ciriacy-Wantrup, S.U.
Journal of Farm Economics, Vol. 43 #2, May 61.

"New Horizons in Water Resources Administration."
Fox, Irving K.
Public Administration Review, Vol 25 #1, March 65.

Urban Planning Aspects of Water Pollution Control.
Institute of Urban Environment
Columbia University Press, New York, 1969.

The Ecology of Waste Water Treatment.
H. A. Hawkes
Pergamon Press, Oxford, 1963.

Quality of the Environment: An Economic Approach to Some Problems in Using Land, Water and Air
Herfindahl, Orris C. and Kneese, Allen U.
Resources for the Future, Inc., Johns Hopkins Press, Baltimore, 1965.

"Water Resources and Regional Economic Growth in the U.S., 1950-60."
Southern Economic Journal, Vol 33, #4, April 1968.

"The Economy, Energy and the Environment -- A Background Study."
J.E.C., Environmental Policy Division
Library of Congress, Sept. 1, 1970.

A Practical Guide to Water Quality Studies of Steams.
F. W. Kittrell, Special Consultant
National Field Investigations Center
Cincinnati, Ohio U.S. DOI-FWPCA, 1969

Water Pollution - Economic Aspects and Research Needs.
Kneese, Allen V.
Resources for the Future, Washington, D. C., 1962.

Approaches to Regional Water Quality Management.
Kneese, Allen V.
Resources for the Future, June 1967.

"Hydrology for Urban Land Planning - A Guidebook on the Hydrologic Effects of Urban Land Use."
Leopold, Luna B.
Geological Survey Circular 554
U.S. Department of Interior, Washington, D. C., 1968

The Practice of Water Pollution Biology
Kenneth M. Mackenthun, Chief, Technical Studies Branch
U.S. DOI-FWPCA
Division of Technical Support, September 1969.

Estimated Use of Water in the U.S., 1950 Survey.
MacKichan, K. A.
Circular H5 (50 + 456 (61))
US Geological Survey Circular

"Price Policy and Land Value Taxation for Urban Water Supplies."
Milliman, Jerome W.
American Journal of Economics for Sociology, Vol 25, #4, Oct. 66, 379-383.

Waste Management and Control
National Academy of Sciences - NRC
Committee on Pollution, Washington, D. C., 1966.

Water Quality Criteria.
Report of the National Technical Advisory Committee to the Secretary of the Interior, Federal Water Pollution Control Administration, Washington, D. C. Apr. 1968

The Economics of Industrial Waste Production and Disposal
Smith, Frank A.
PhD Dissertation, Northwestern University, 1968

"Effects of Increased Water Demands on Three New England Water Companies."
O'Connor, Leo F.
Journal of the American Water Works Association
Vol. 58, #11, Nov. 66, pp 1374-1375.

"Urban Area Water Consumption: Analysis and Projections."
Robert J. Saunders
The Quarterly Review of Economics and Business, Vol 9, No. 2, Summer, 1969.

A Systems Analysis Model of Urbanization and Change.
Steinitz, Carl; Rogers, Peter.
MIT Report No. 20, MIT Press, Cambridge, 1970

The Cost of Clean Water and Its Economic Impact, Vol. IV.
Projected waste water treatment costs in the organic chemical industry.
Cyrus W. Rice and Co., Pittsburgh, Pa.
U.S. DOI-FWPCA, June 1969.

The Nation's Water Resources
U.S. Water Resources Council
Washington, D.C., 1968

Major Uses of Land and Water in the U.S. with Special Reference to Agriculture Summary for 1964.
US Department of Agriculture
Economic Research Service, Agricultural Economic Report #149, Nov. 68.

Water Resources Activities in the US - Water Requirements for Pollution Abatement
Select Subcommittee on National Water Resources
U.S. Senate, S. Res. 48, 86th Congress, July, 1960.

APPENDIX F

The Units of Measure Used for Pollutants in the RIVER BASIN MODEL

The seven pollutant types are represented in the RIVER BASIN MODEL (RBM) with units of measure that were thought to be easiest for a layman to deal with. That is, the normal units of measure were not used when it was thought a typical user of the model would not have a "feeling" for the measure. Thus, metric system notation was avoided.

To some users of the RIVER BASIN MODEL, these measurement adjustments probably appear unusual and/or unrealistic. In order to convert the simplified measures of the model back to more standard notation, the following table may be used:

Pollutant Type	RIVER BASIN MODEL Measure	Corrected Measure
BOD	LBS/MG	.12 mg/l
Chlorides	LBS/MG	.12 mg/l
Nutrients	LBS/MG	.12 mg/l
Coliform	PARTS/MG	5000/100 ml

The temperature measure used in RBM are deviations from 75°F. To convert these farenheit measures to centigrade readings, the deviations would be as indicated below:

Manufacturing Type	Present RBM (F°)	Altered RBM (C°)
FO (Foods)	9	5.04
TA (Textiles)	18	10.08
PA (Paper)	16	8.96
CR (Chemicals)	4	2.24

Using centigrade, the deviations would be from 24°C.

The standard conversion from F° to C° is:

$$C^\circ = 5/9\ (F^\circ - 32)$$

Modification in Parameters for the RIVER BASIN MODEL

Brief inspection of the water parameters of the model by several knowledgeable people at EPA has revealed that modifications are called for in the amounts of pollution generated by land-use activities and in the effectiveness levels of the various treatment types.

Pollution Generated by Land-Use Activities

Figure 21 in the RBM Overview shows the amounts of pollution generated by each of the land-use types. A typographical error was readily noticed in the coliform generated by residential land uses vis-a-vis the other land uses. The residential generation of coliform pollution should be increased by a factor of 100.

A check against the IRT-229-R Study* showed that the BOD generated per MG of water could be changed for the following industrial activities:

	BOB per MG	
Industry	RBM	IRT Study
FL	600	0
SB	500	0
MP	1000	342
MF	500	0
NL	400	2000
EL	800	2000
TE	500	1700

---

*A new source of data on the water pollution generated by various water users has been discovered that might improve upon the numbers used in the present version of the RIVER BASIN MODEL. The source is IRT-229-R, "Environmental Implications of Technological and Economic Change for the United States, 1967-2000. An Input/Output Analysis." (June 1971).

The following water pollutants are measured by land-use type in the IRT Study:

COD - substances with chemical oxygen demand
BOD - substance with biological oxygen demand
RO - refractory organics
SS - suspended solids
DS - dissolved solids
N - nitrogen
P - Phosphate compounds

The IRT Study omits toxic chemicals and atomic radiation (HLW) and persistent pollutants (CL) which are accounted for in the RIVER BASIN MODEL.

BOB per MG

Industry	RBM	IRT Study
FO	6000	10000
TA	6000	4684
PA	3000	3333
CR	2000	4000

The IRT Study also indicates that in the RBM, BOD for residential users is about half of what it should be per millions of gallons of water used.

Effectiveness of Treatment Types

EPA personnel in the Water Quality Office thought that the treatment effectiveness for BOD and Chlorides was overstated. Therefore, it was decided when the model is changed to reduce the effectiveness of primary treatment on BOD to 35 percent and to increase the effectiveness of secondary treatment to 90 percent (these estimates are identical to those contained in the IRT Study). Furthermore, the percent elimination of chlorides will be reduced to zero for secondary treatment and 50 for tertiary treatment. Tertiary treatment effectiveness on nutrients will be dropped from 99 percent to 95 percent.

Cost of Treatment

In RBM, the cost of treating an MG of polluted water is a function of the type and size of the treatment facility for municipal plants. The least efficient tertiary water treatment plant (most expensive) costs $300 per MG and the most efficient plant costs $195/MG. All industrial treatment plants have the same cost per MG for each of the treatment types. The IRT Study showed the following costs by type of activity for secondary treatment:

FO	$392/MG
TA	322
PA	405
CR	297
MP	301
NE	239
EL	270
TE	230

The RIVER BASIN MODEL has a $50 cost per MG for chlorination, $100 for primary, $200 for secondary, and $300 for tertiary. These could be easily changed to be closer to the IRT figures.

The RIVER BASIN MODEL cost figures relate to the 1960 base year prices, whereas the IRT study figures relate to the 1967 base year. Thus, part of the explanation for the higher figures in the IRT Study is due to price inflation.

1 *Accession Number*
W

2 *Subject Field & Group*
05 01

SELECTED WATER RESOURCES ABSTRACTS
INPUT TRANSACTION FORM

5 *Organization*
Envirometrics, Inc., Washington, D. C.

6 *Title*
THE RIVER BASIN MODEL: AN OVERVIEW

10 *Author(s)*
House, Peter W.
Patterson, Philip D.
Cooper, Janice
O'Connell, Greg

16 *Project Designation*
EPA, ORM Contract No. 14-12-959

21 *Note*

22 *Citation*

23 *Descriptors (Starred First)*

*Water Pollution, *Water Pollution Effects, *Treatment, *Computer Programs, *Water Users, *Regional Analysis, *Training, Waste Water Disposal, Recreation, Planning, Grid Systems, Water Costs, Degredation, Population, Prices, Employment, Farms, Environmental Effects, Floods, Jurisdiction, Economic Growth

25 *Identifiers (Starred First)*

*Land Uses, *Population Migration, *Social Dissatisfaction, *Resource Allocation, *Decision-Making Model,*Gaming-Simulation Model, Holistic Model,

27 *Abstract*

The RIVER BASIN MODEL is a man-machine simulation model that represents the supply of, demand for, and quality of water within a geographical area that contains a full range of economic, social, and government activities. The model may be used to represent any actual or hypothetical river basin area for educational and research purposes. Users of the model are given control over all the resources of the local area being represented. Some of the local activities withdraw water directly from the water system and return their effluent to that system (either treated or not). Most of the businesses and population of the local system use municipally supplied water which also must be withdrawn from thelocal water system and treated if necessary. The municipal treatment of sewage is a decision that is made in light of local considerations, such as cost, pollution levels, intergovernmental cooperation, etc.

The output from the operating programs of the RIVER BASIN MODEL computer package illustrate the impact that the water system has on such phenomena as housing selection, employment, time allocation and the activity pattersn that result, and government budgetary activity (revenue collection and disbursement). The users of the model may make a wide range of private and public policy decisions which affect the simulations for each of these phenomena, and which impact the environmental quality of the represented area. (Patterson - Envirometrics)

Abstractor
Philip D. Patterson

Institution
Envirometrics, Inc.

WR:102 (REV. JULY 1969)
WRSIC

SEND, WITH COPY OF DOCUMENT, TO: WATER RESOURCES SCIENTIFIC INFORMATION CENTER
U.S. DEPARTMENT OF THE INTERIOR
WASHINGTON, D. C. 20240

☆U.S. GOVERNMENT PRINTING OFFICE: 1972-484-484-/196